AIRCRAFT SYSTEM MAINTENANCE

Mr. M.Tozan
KFUPM

Objectives

- Become familiar with aircraft ground handling procedures
- Understand operation principles, components & maintenance practices of aircraft systems
- Provide you with basic knowledge of non destructive inspection methods
- Improve your understanding for analyzing, developing and managing aircraft maintenance programs

Course Outline

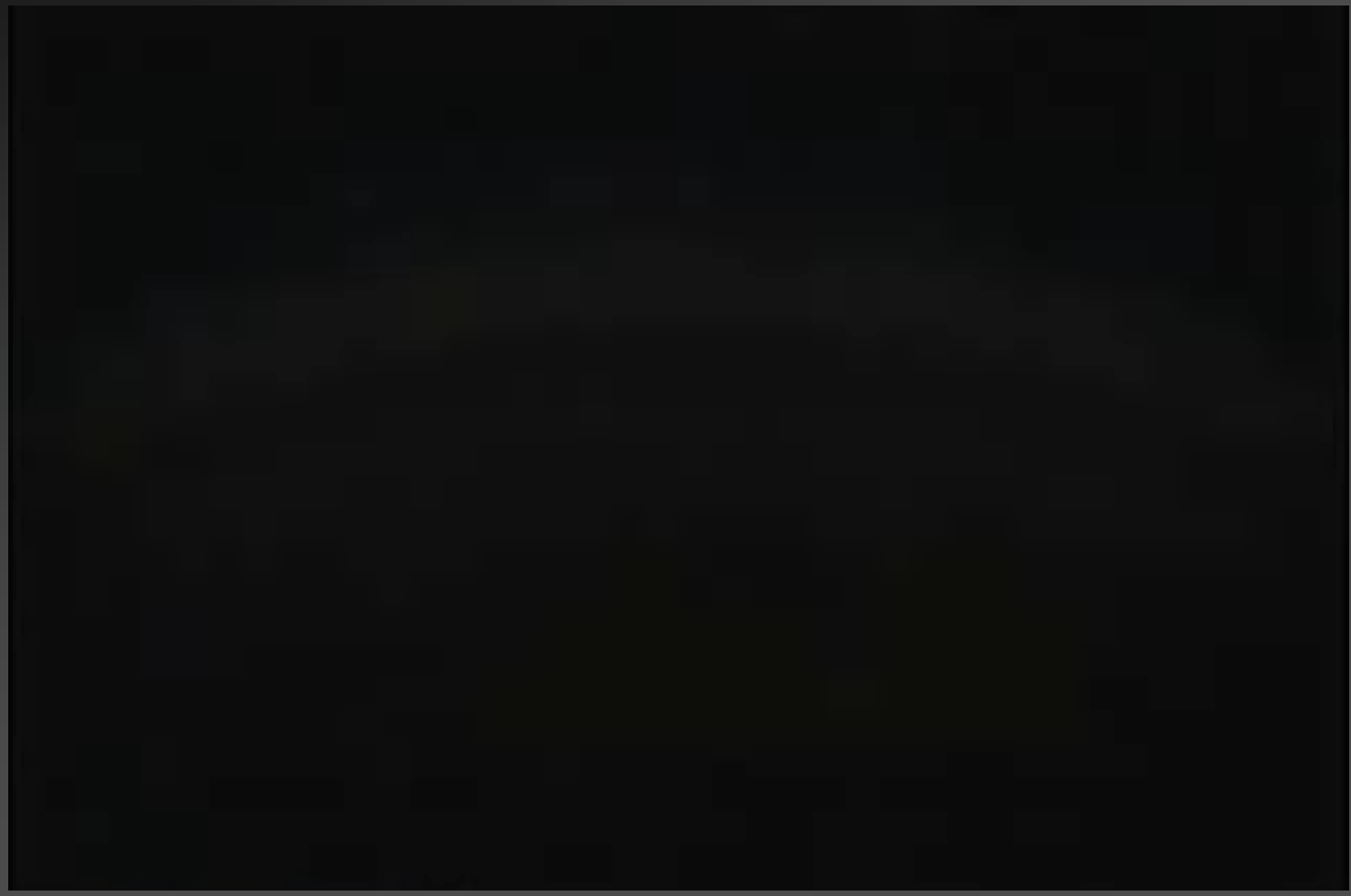
- Aircraft Ground Handling
- Aircraft Systems/avionics/engine
- Corrosion and Aircraft Inspection Methods
- Aircraft Maintenance Planning & Management

Aircraft Ground Handling

Sources of Hazard in Ground Operations

- Fuel
- Electricity
- Compressed gases
- Spilled oil and grease
- Foreign Objects
- Running aircraft

Be careful around running aircraft



It is also better to be careful in front of the running engine

Ground Support Services & Operations

- Electric &Hydraulic service
- Air conditioning & Heating
- Refueling
- Towing& taxiing
- Baggage loading
- Passenger boarding
- Catering
- Others

Ground Support Equipments (GSE)

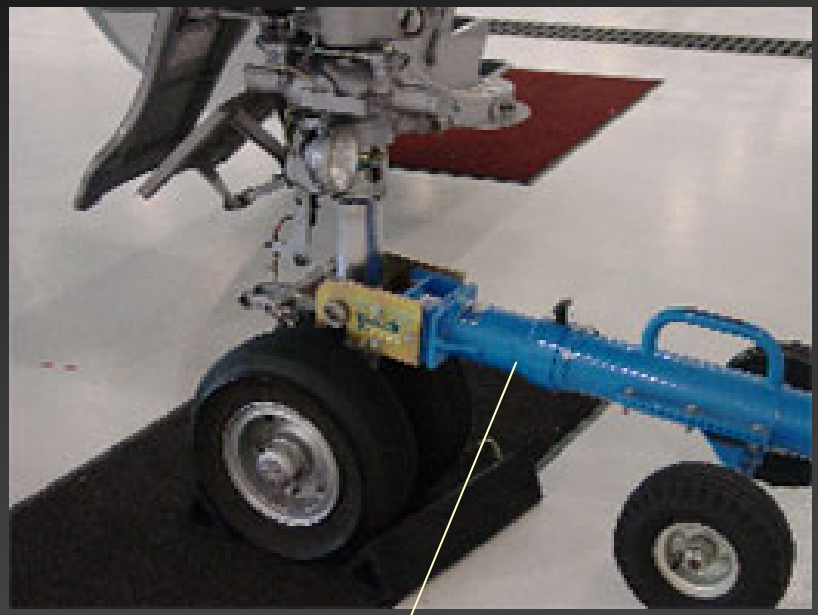
GPU (Ground Power Unit-Electricity)

Air conditioning unit

Air Starter

Refueling

Aircraft towing



TOWBAR

WING WALKER

Aircraft should only be towed by appropriate vehicle

Example : B-777 Ground servicing

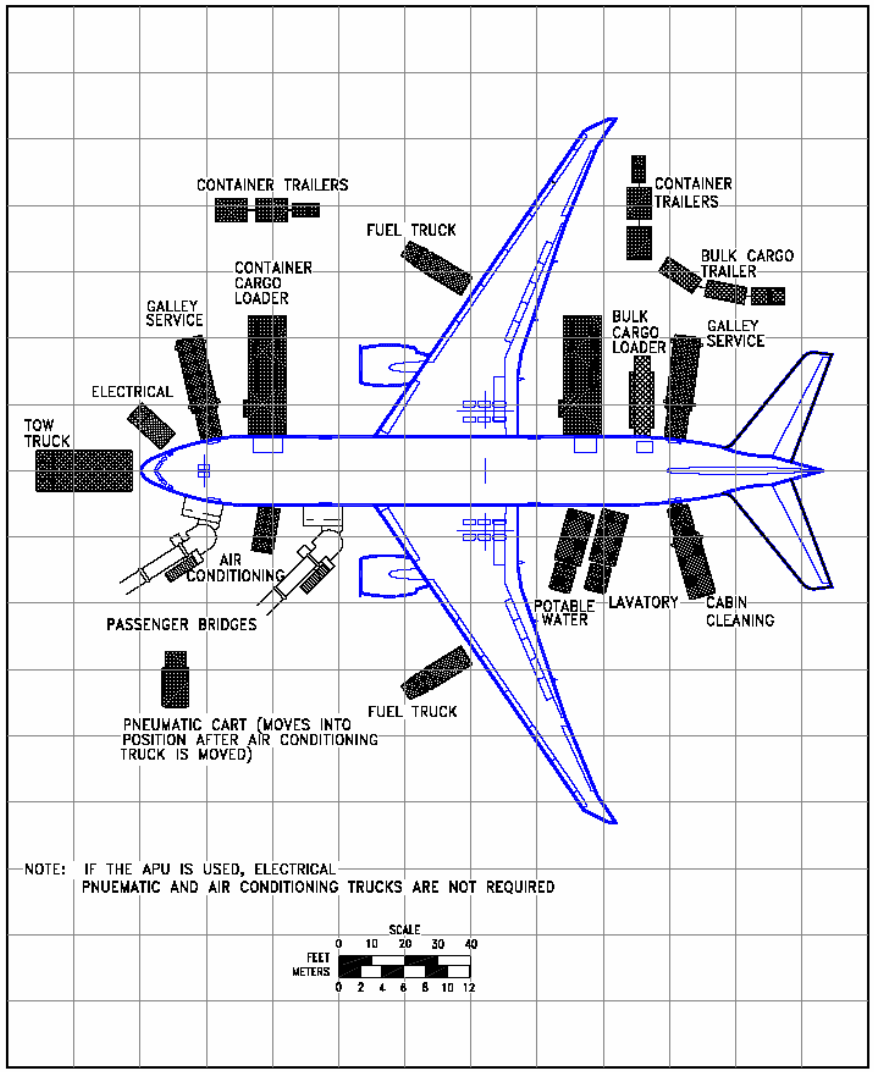
Fuel

Elect.

a/c

Tow

air



5.1.1 AIRPLANE SERVICING ARRANGEMENT - TYPICAL TURNAROUND

MODEL 777-200LR

water

Food

Cargo

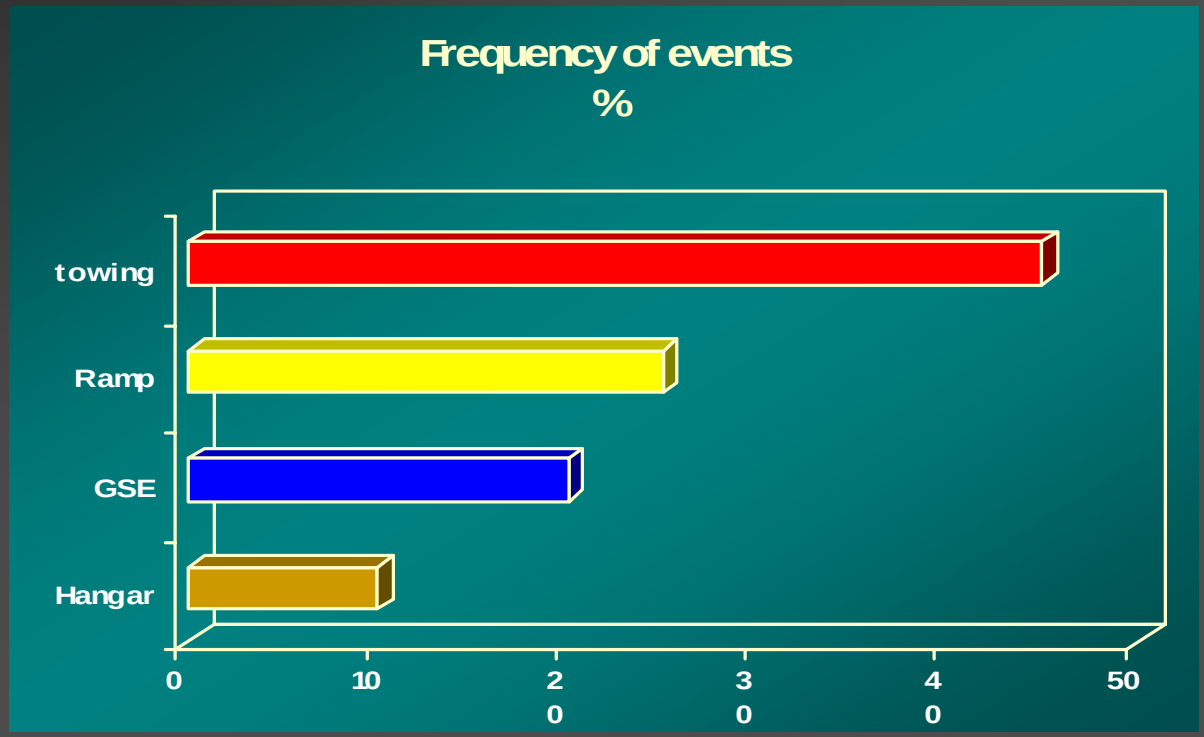
Lav

Clean

A typical ground handling of an aircraft

Most significant risk factors for ground damages

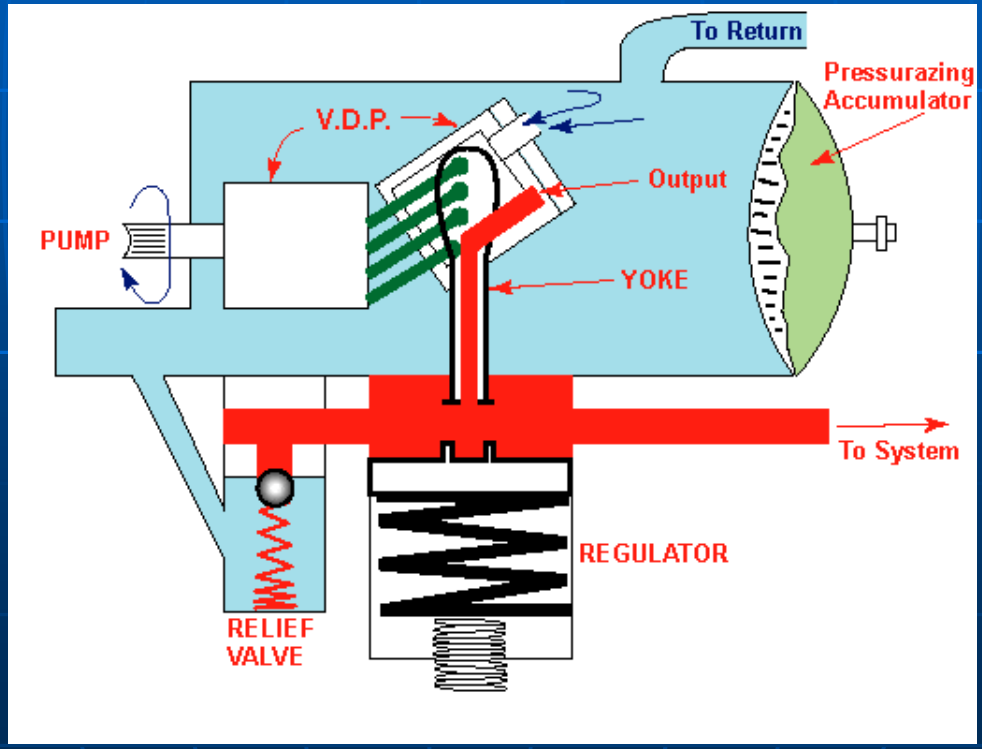
1. Towing
2. Ramp movements
3. Ground service equipment (GSE)
4. Hangar movements



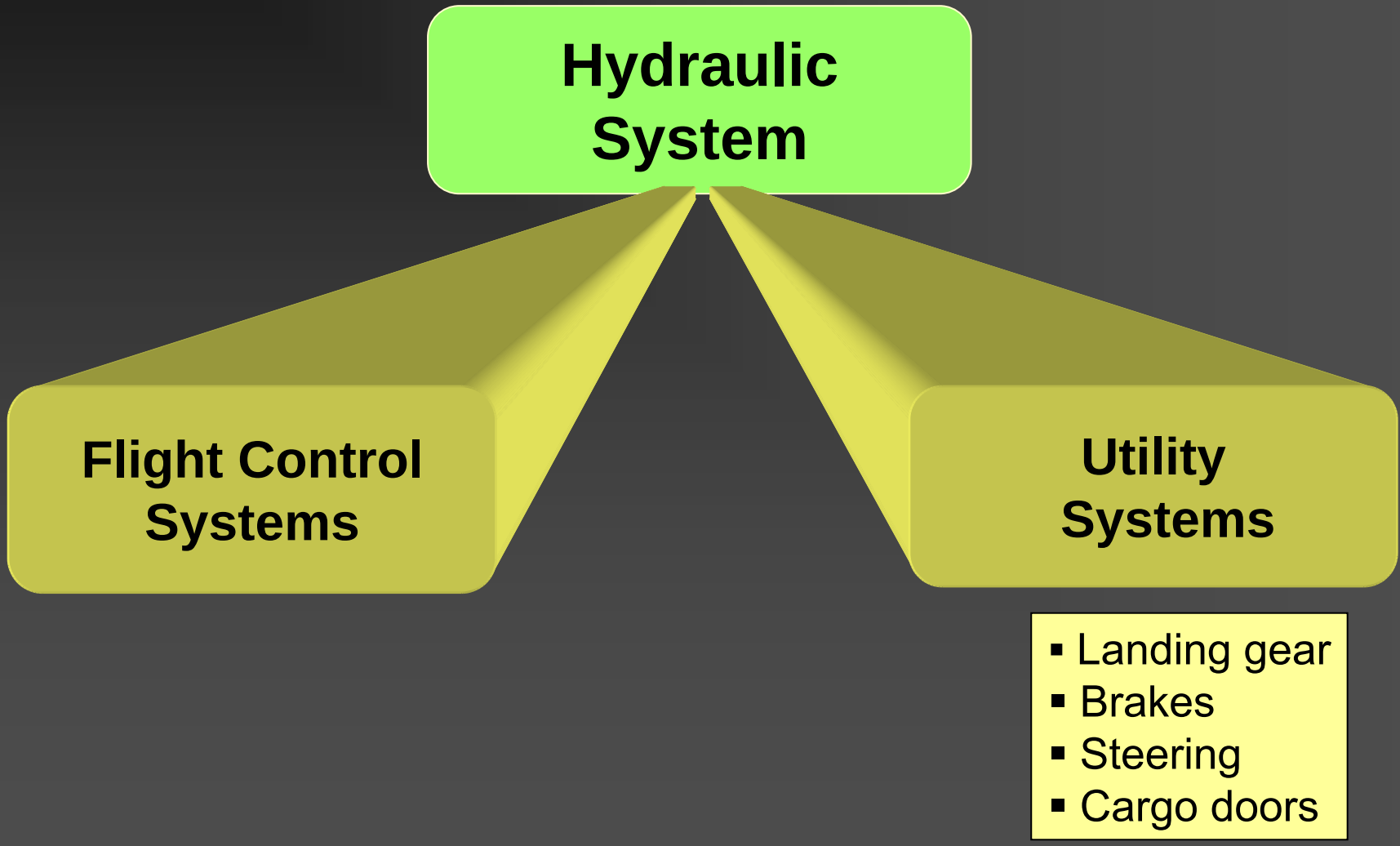
IATA (International Air Transport Association) estimates that ground damages cost $5 billion/yr

AIRCRAFT SYSTEMS

AIRCRAFT HYDRAULIC SYSTEM



Hydraulic powered systems



Hydraulic fluids

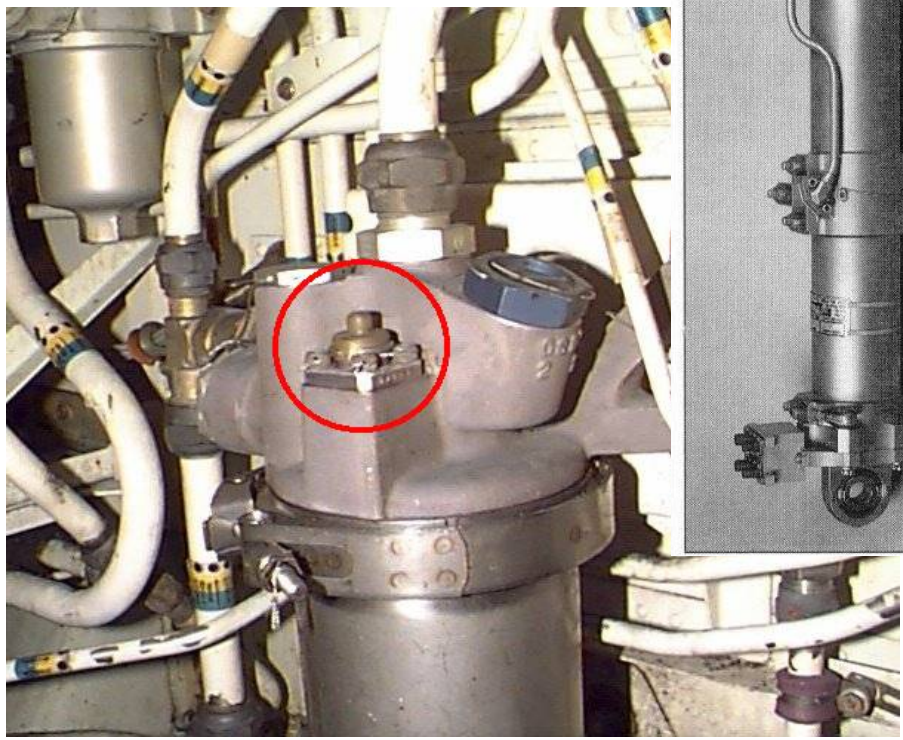
MINERAL BASED HYDRAULIC

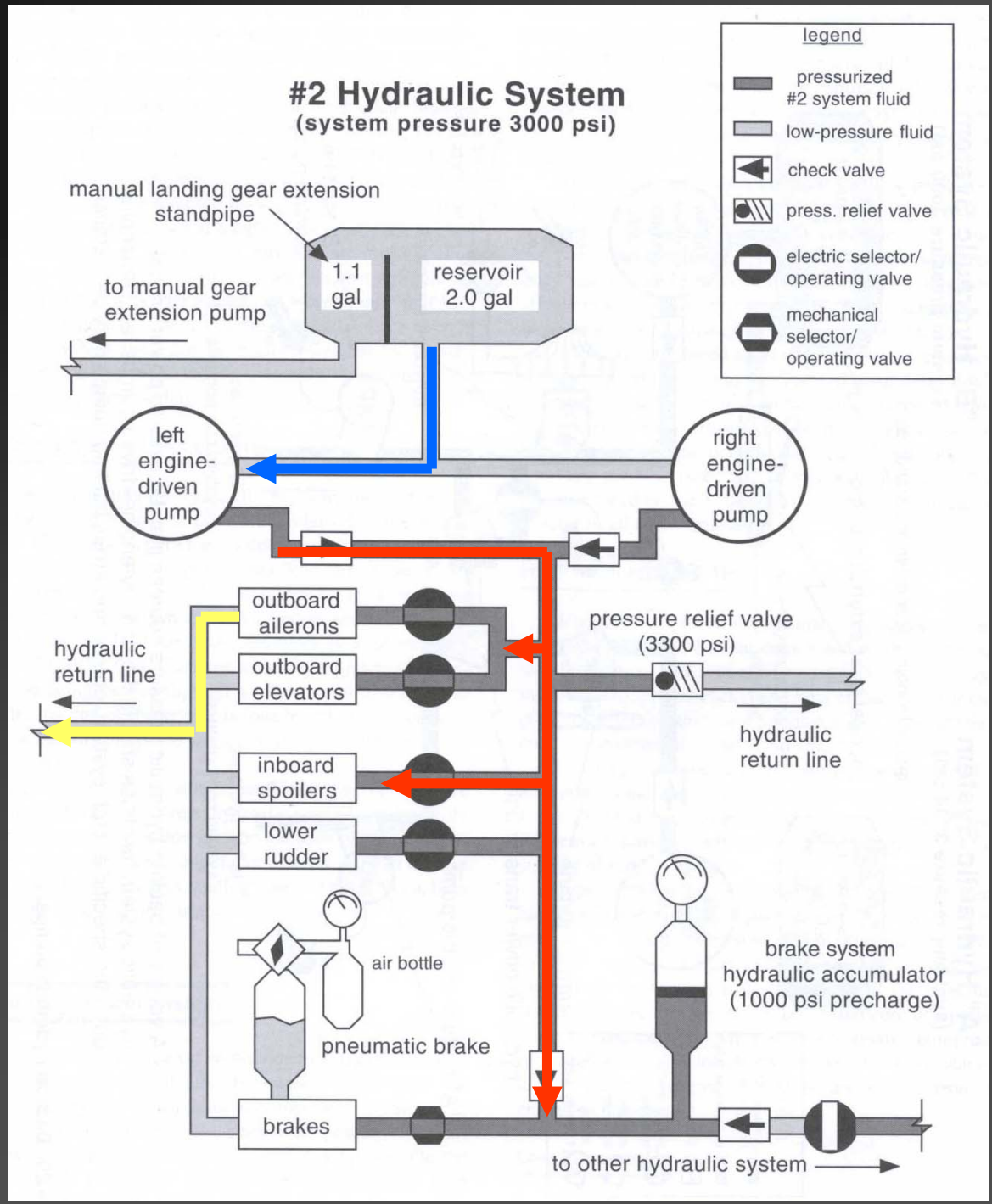
SYNTHETIC (SKYDROL) HYDRAULIC

Basic hydraulic system components

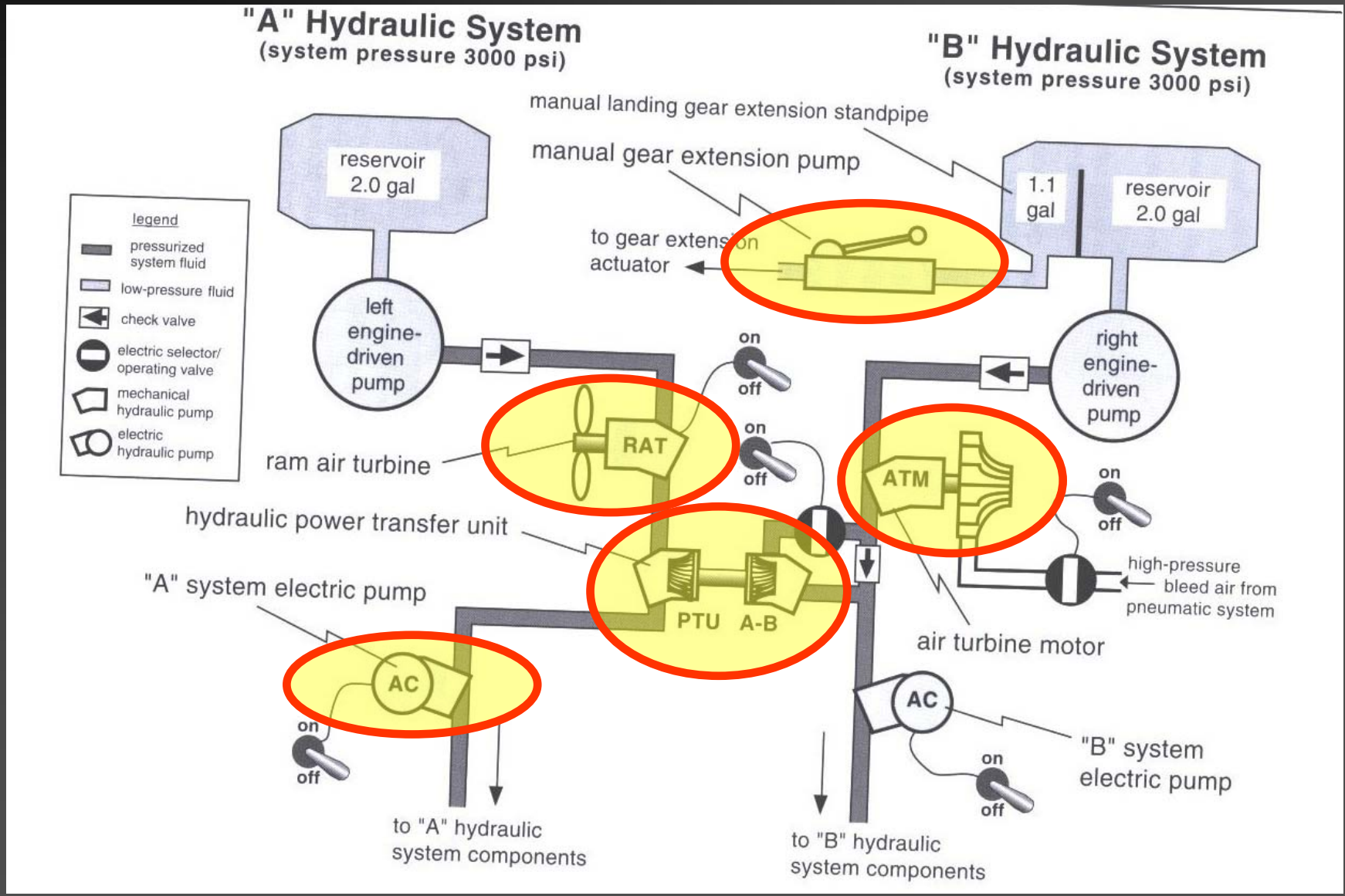
- Reservoirs
- Pumps
- Valves
- Accumulators
- Filters
- Actuators
- Back-up systems

Hydraulic system components




#2 Hydraulic System
(system pressure 3000 psi)
legend
pressurized #2 system fluid
low-pressure fluid
check valve
press. relief valve
electric selector/ operating valve
mechanical selector/ operating valve
manual landing gear extension standpipe
1.1 gal
reservoir 2.0 gal
to manual gear extension pump
left engine-driven pump
right engine-driven pump
outboard ailerons
outboard elevators
inboard spoilers
lower rudder
hydraulic return line
pressure relief valve (3300 psi)
hydraulic return line
air bottle
pneumatic brake
brake system hydraulic accumulator (1000 psi precharge)
brakes
to other hydraulic system

Hydraulic Backup Systems



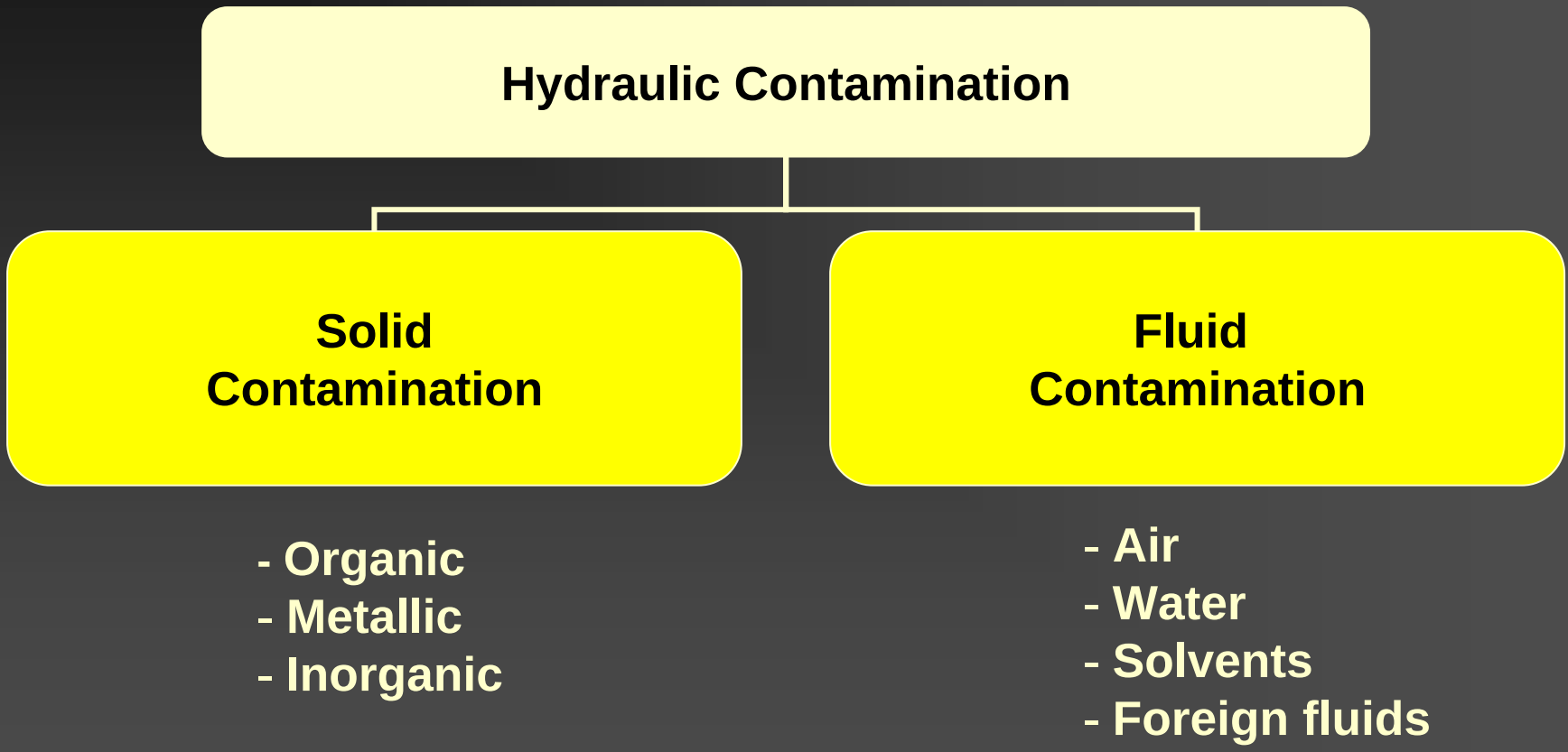
Ram Air Turbine (RAT)

Hydraulic system failures

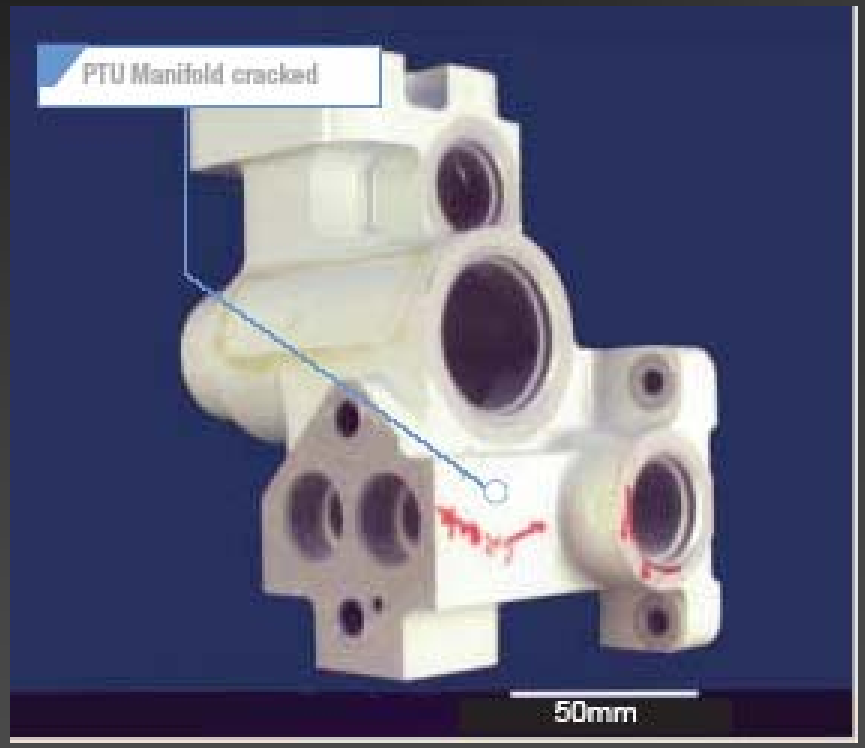
There are two main causes of hydraulic system failures:

- Hydraulic fluid contamination
- Hydraulic leakage

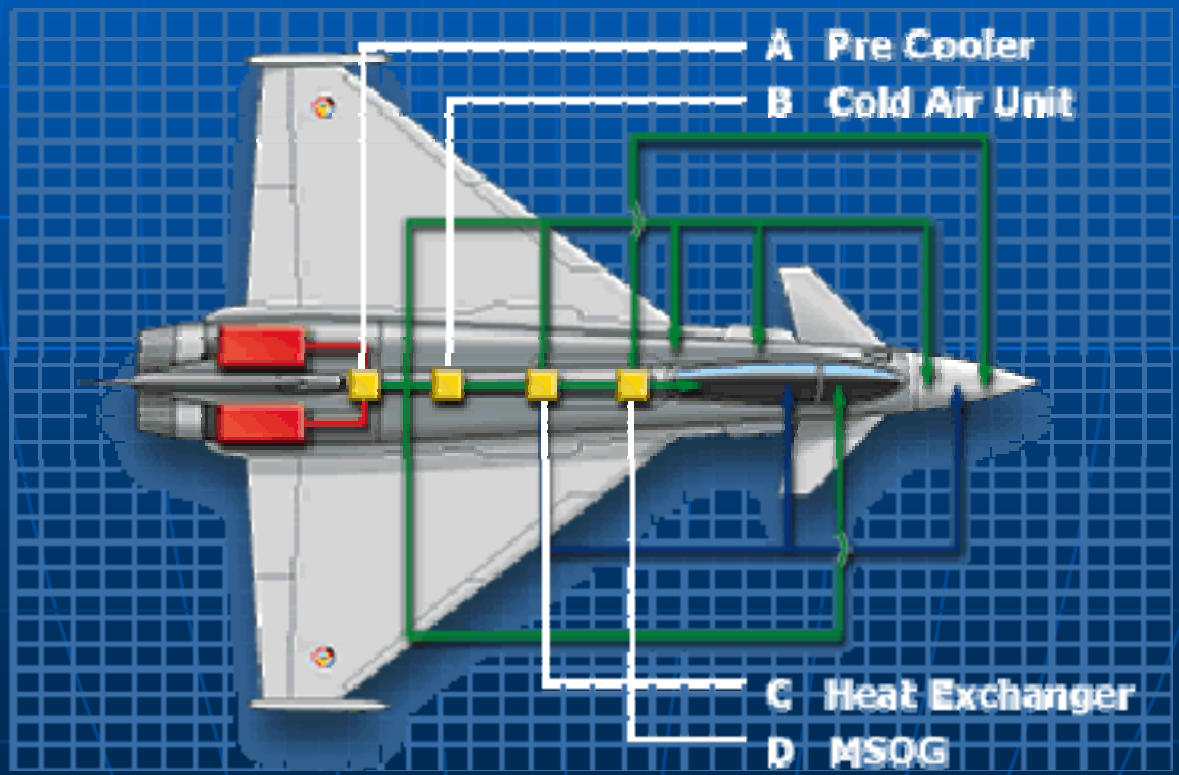
Hydraulic contamination



Hydraulic leakage may come from wrong pipe installation or crack on components



AIRCRAFT PNEUMATIC SYSTEM



Functions of pneumatic system

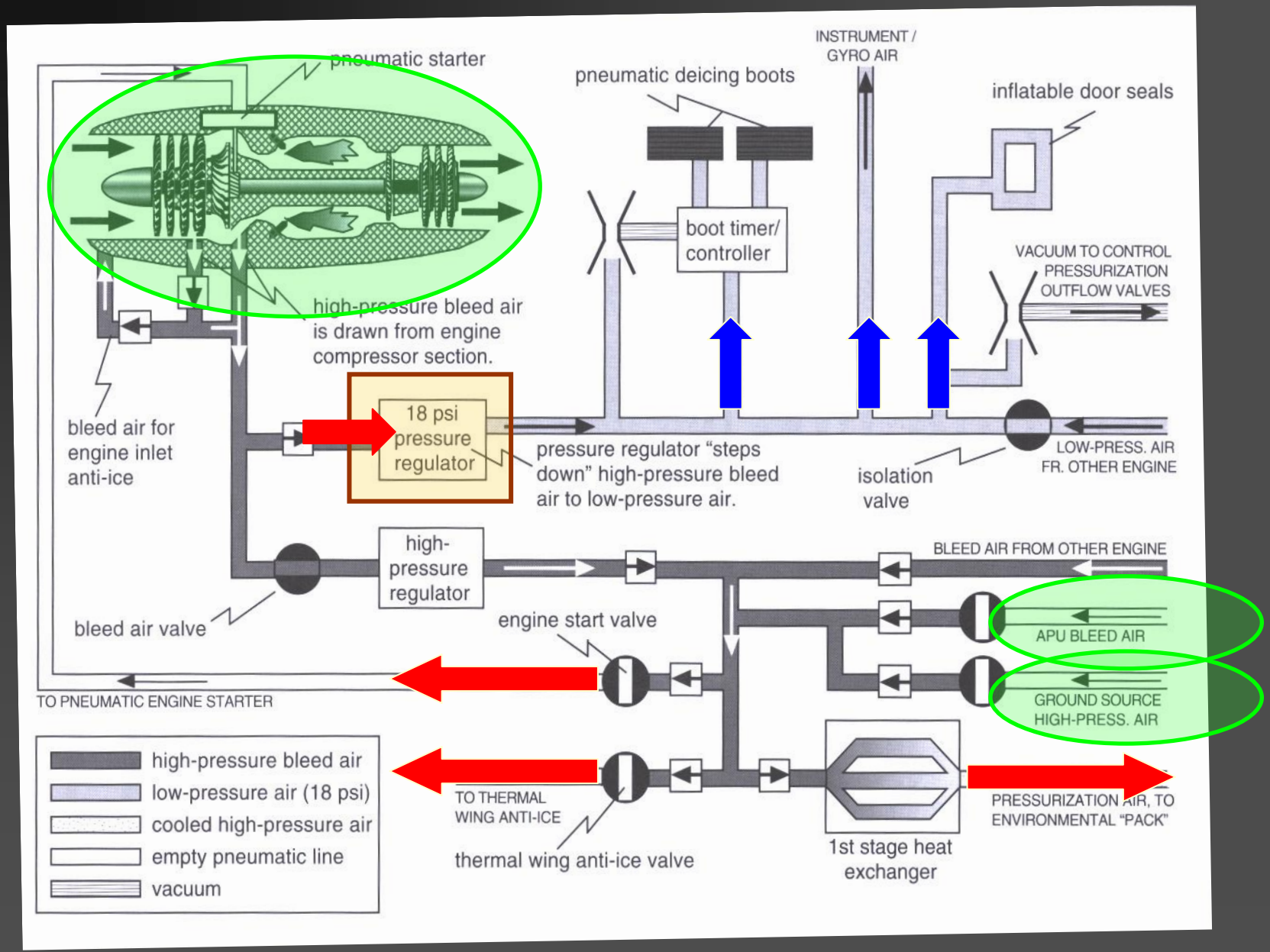
High-pressure system provides power for:

- Engine and wing anti icing
- Operating engine thrust reversers
- Cabin pressurization, heating and cooling
- Powering engine starters

Low pressure system provides power for:

- Driving gyros in the flight instruments
- Deicing boots
- Inflation of door seals to sustain pressurization

Pneumatic system



Auxiliary Power Unit (APU)

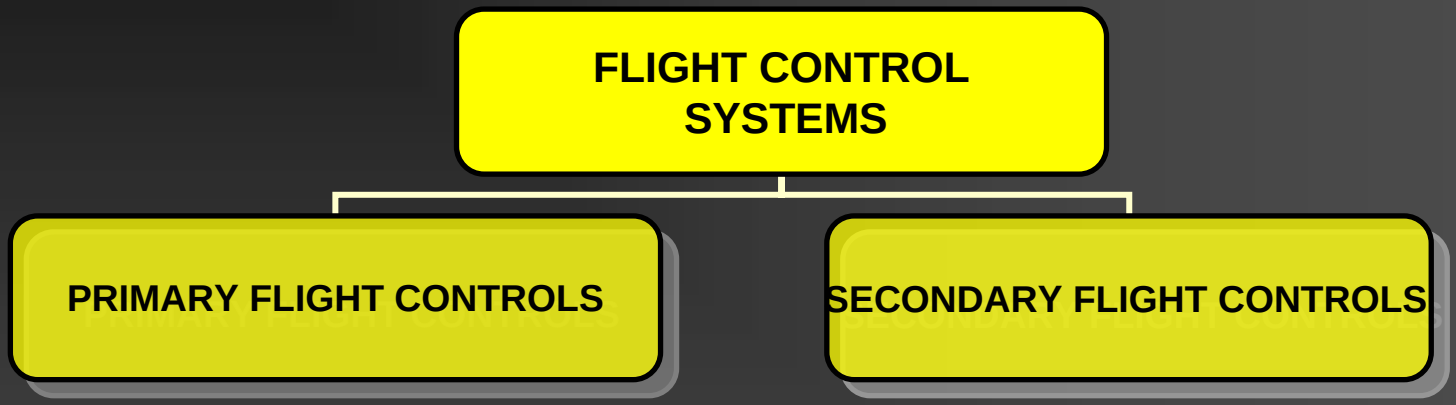
APU functions

- Start engine
- Power generators to provide auxiliary electrical power
- Power environmental systems such as air conditioning
- Provide power for crew functions such as preflight and galley operations

Auxiliary Power Unit (APU)

AIRCRAFT FLIGHT CONTROL SYSTEM

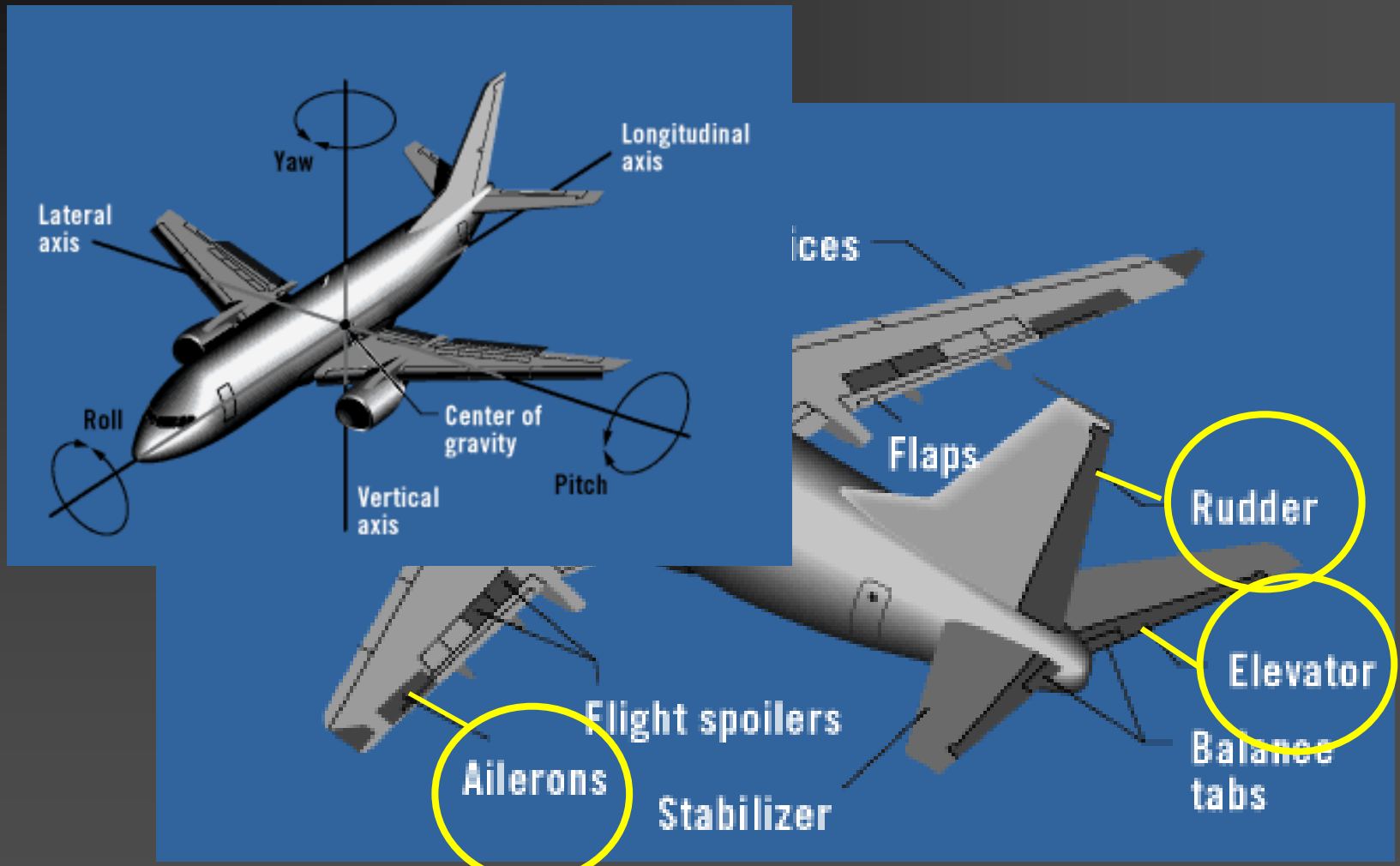
Flight Control Systems



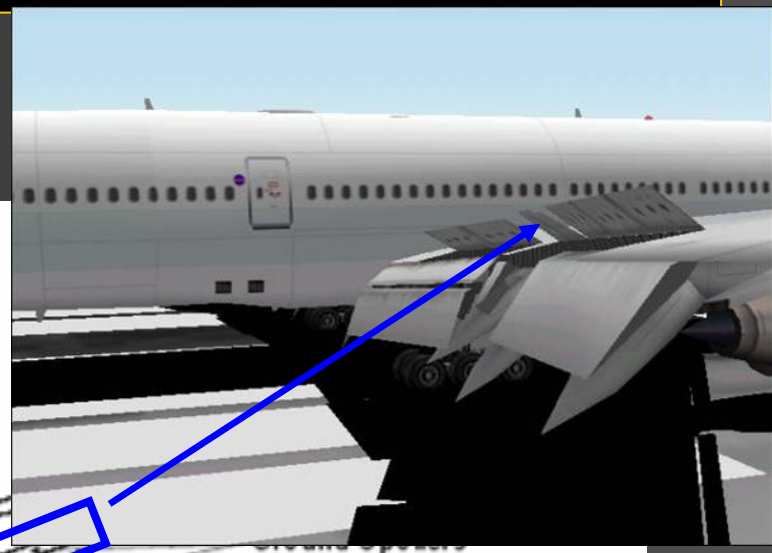
- AILERONS
- ELEVATORS
- RUDDERS

- FLAPS
- LEADING EDGE DEVICES
- SPOILERS
- SPEED BRAKES
- TRIM & CONTROL TABS

Primary Flight Control surfaces

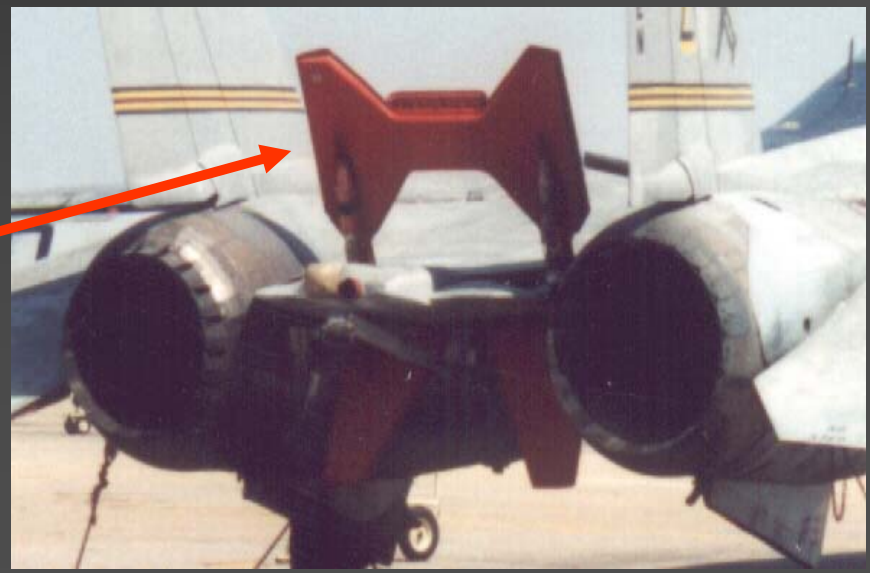


Secondary Flight Control surfaces

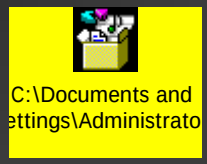


Secondary Flight control surfaces

SPEED
BRAKE



Aircraft flight control surfaces

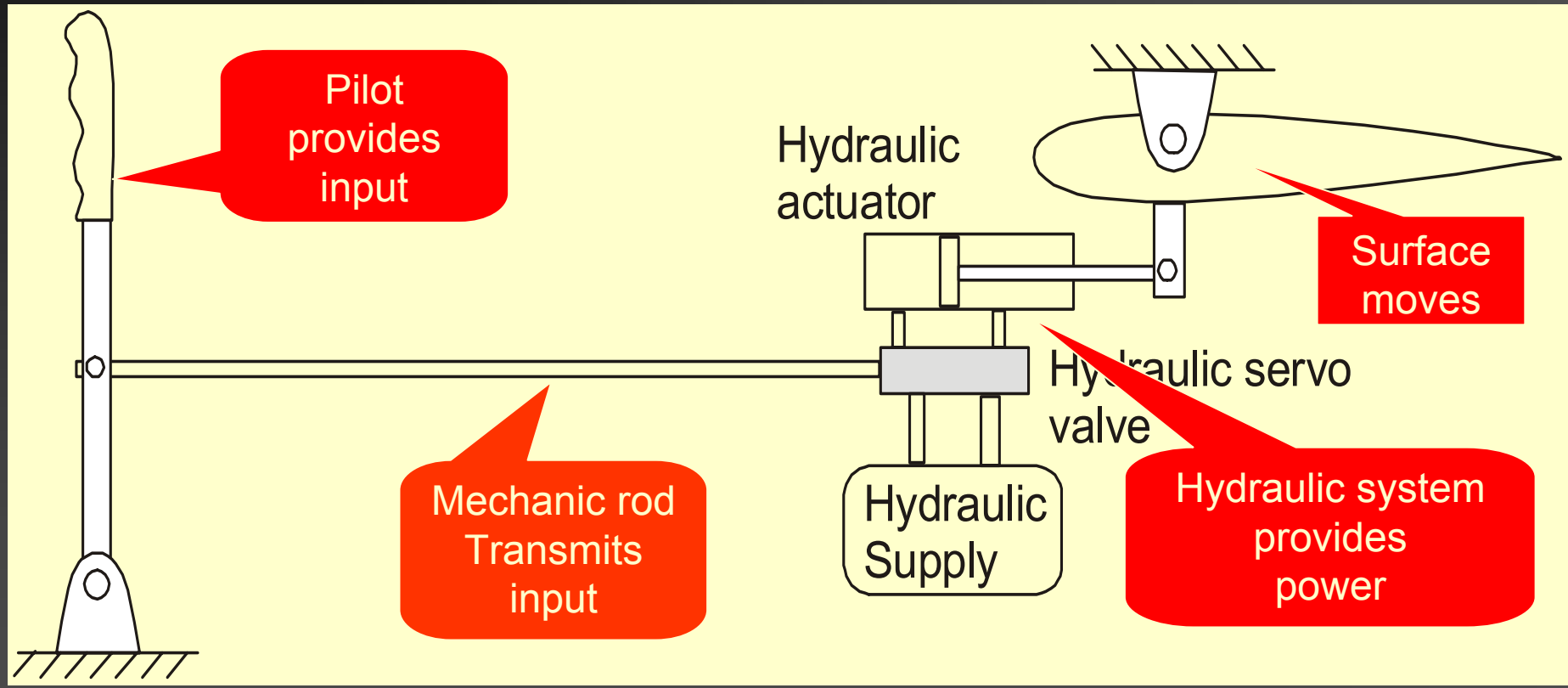


Types of control linkage systems

- Mechanical command & mechanical actuation
- Mechanical command & hydraulic actuation
- Electric signal command & hydraulic actuation (Fly by wire)

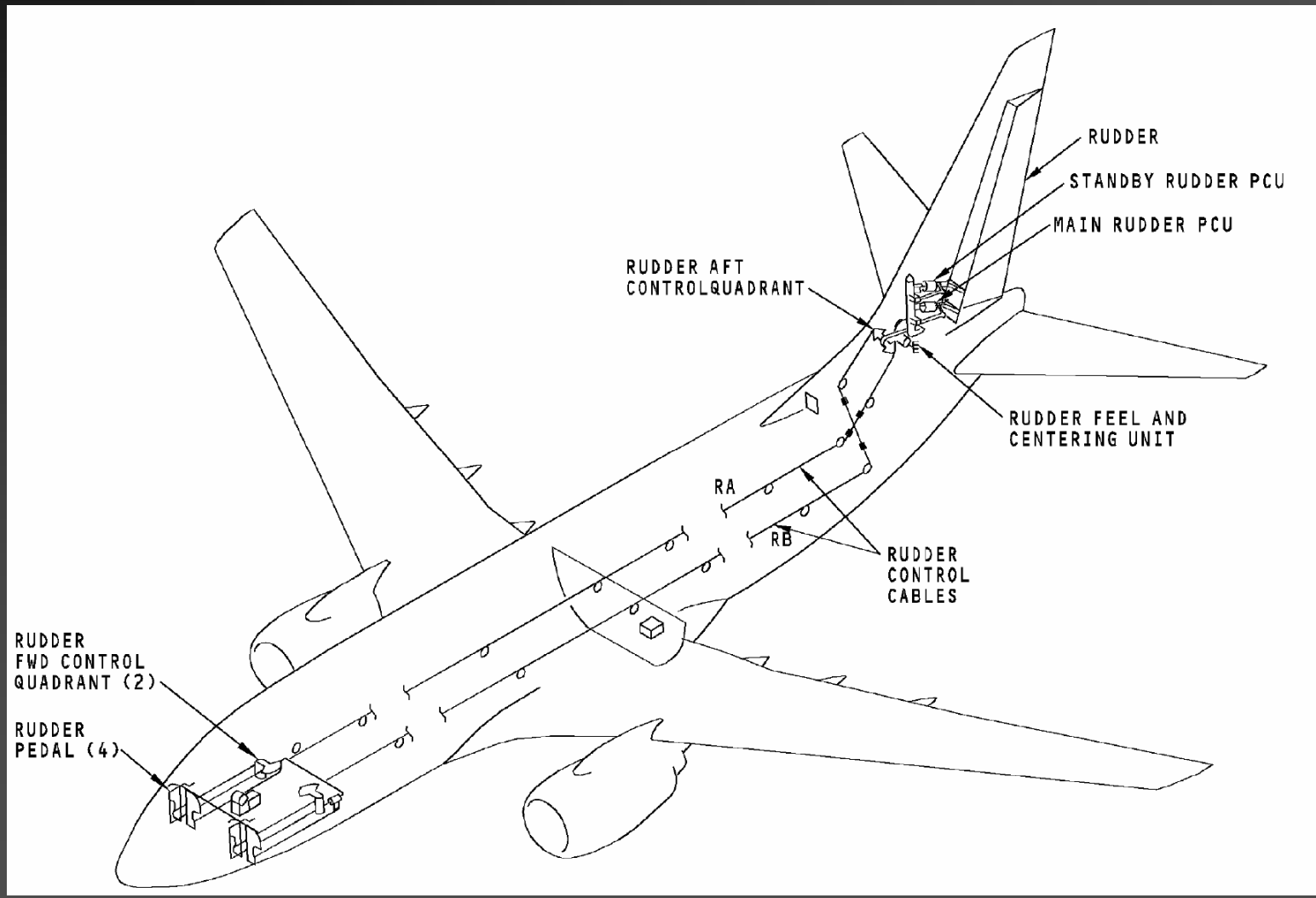
Mechanical command-mechanical actuation

Mechanical command-Hydraulic actuation

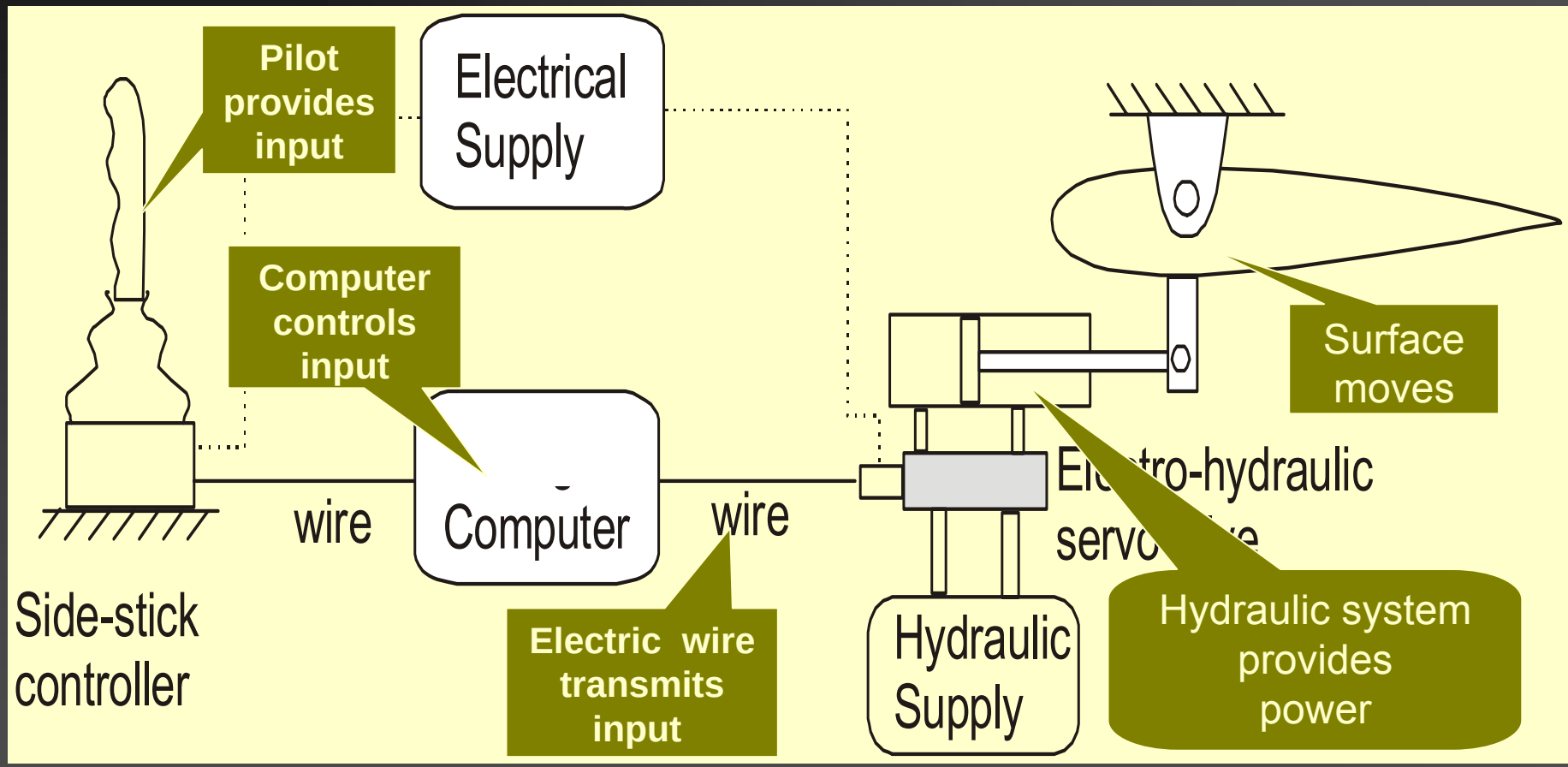


Reduces pilot effort when control hinge moments are large, e.g. large control displacements at high speed

Mechanical command-Hydraulic actuation

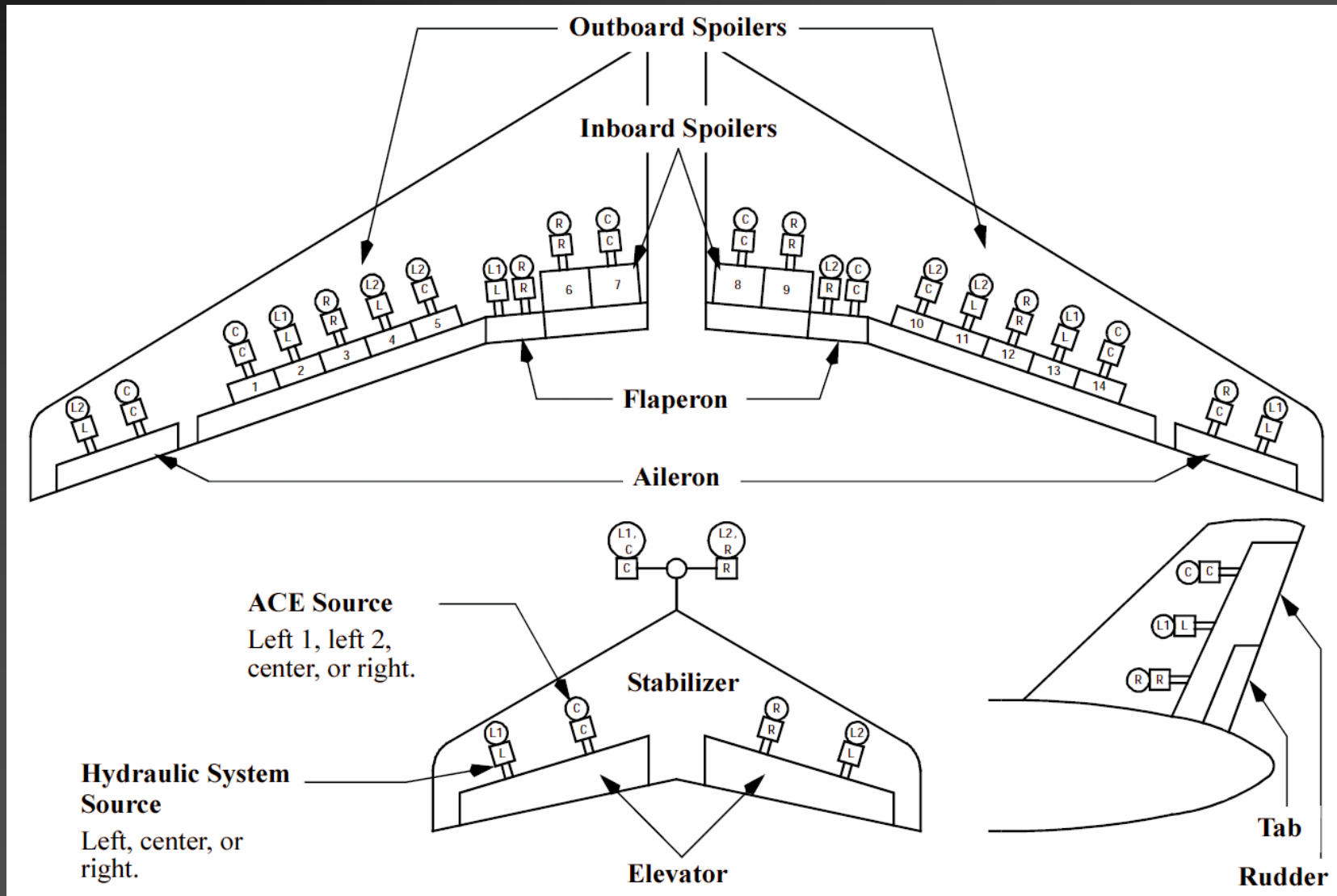


Electrical command- hydraulic actuation



✓Pilot provides input, computer controls the input, electrical wire transmits the input, hydraulic system provides power.

Electrical command hydraulic actuation

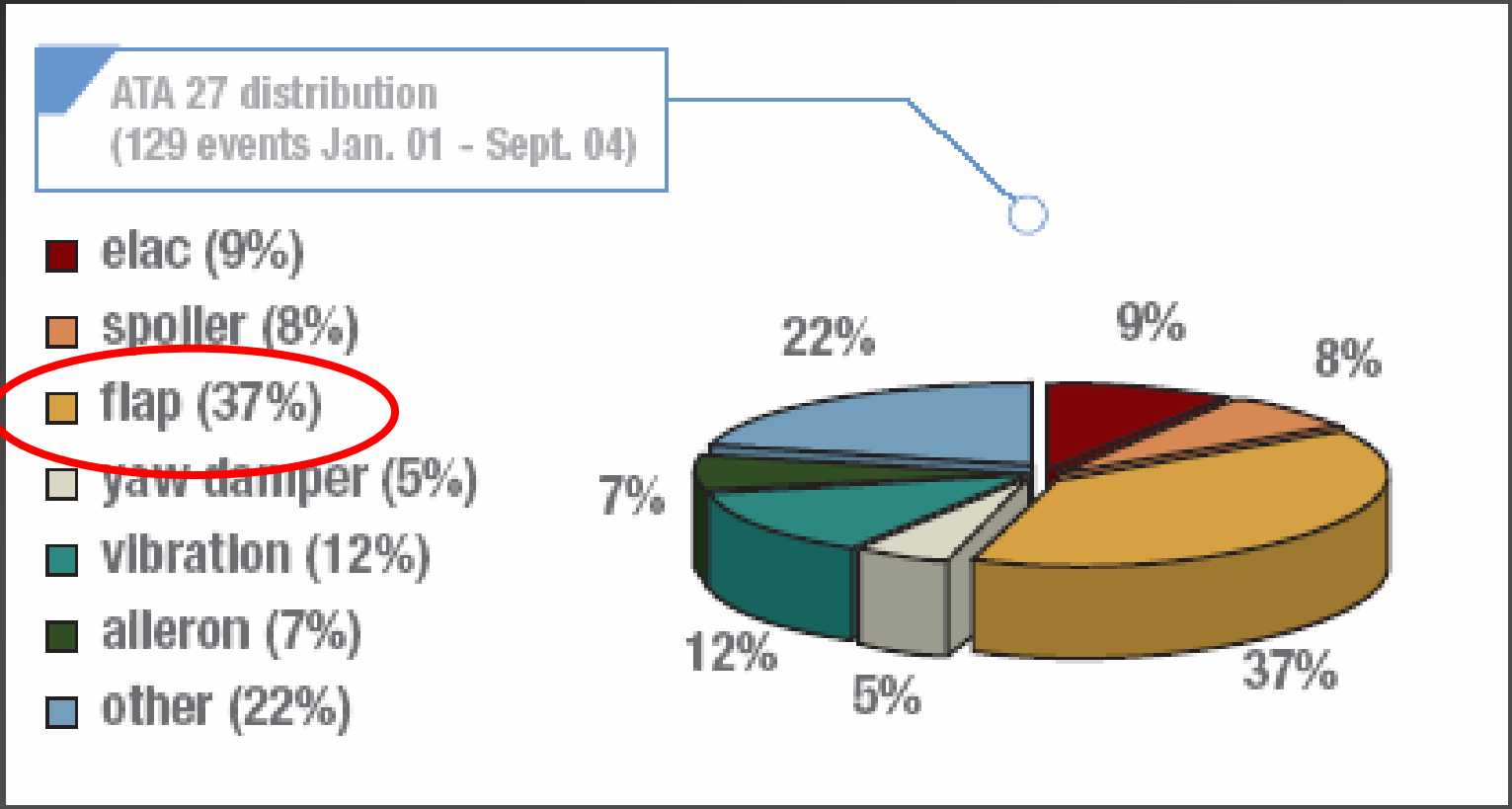


Main reasons for flight control malfunctions

- Maneuvers that have exceeded operational design limits of the control system.
- Corrosion and/or distorted or disconnected linkage.
- Inadequate lubrication and external contamination.

In-flight failures of flight control system

Most significant causes of failures are flaps and vibration.



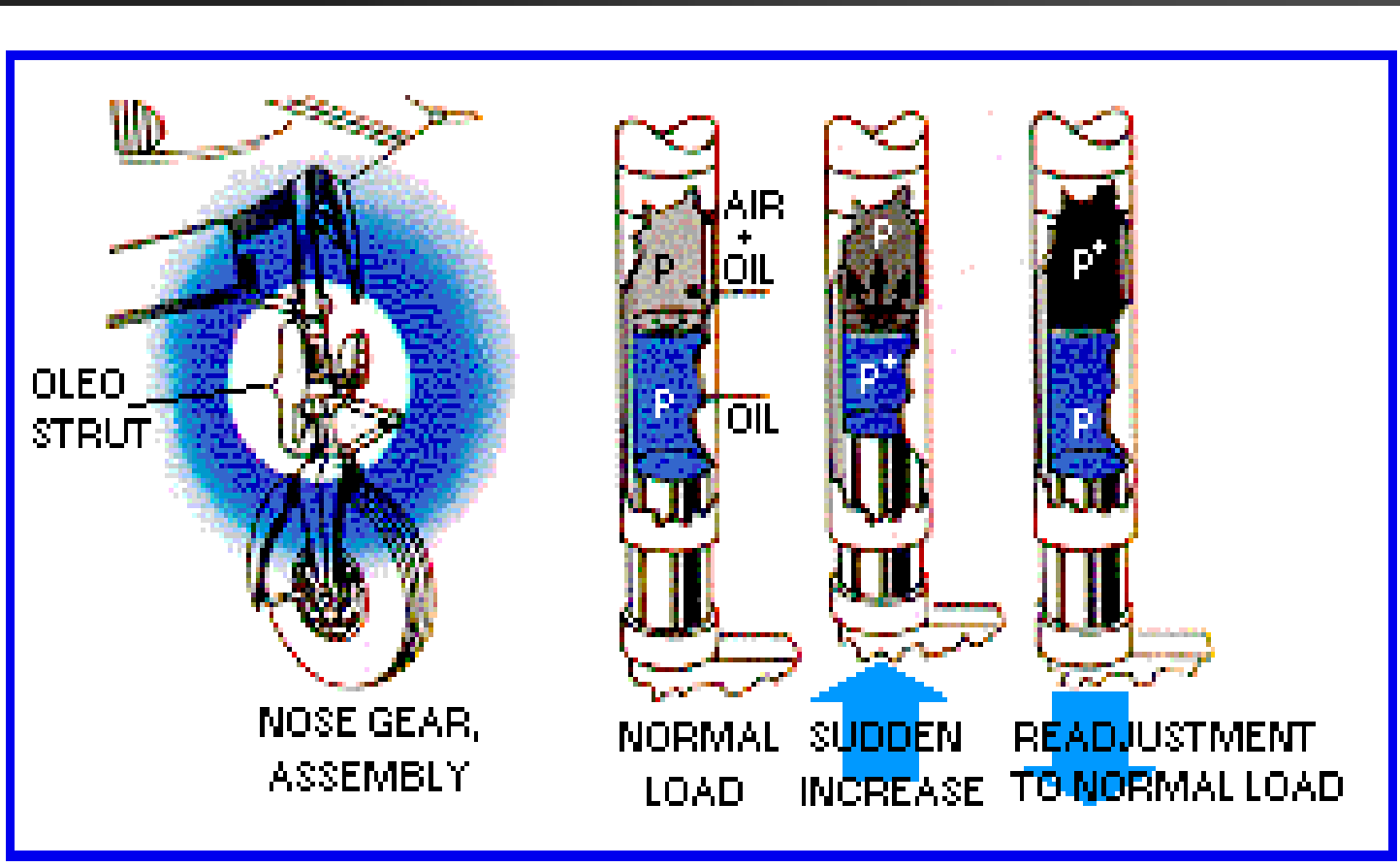
AIRCRAFT LANDING GEAR SYSTEM

Functions of landing gear system

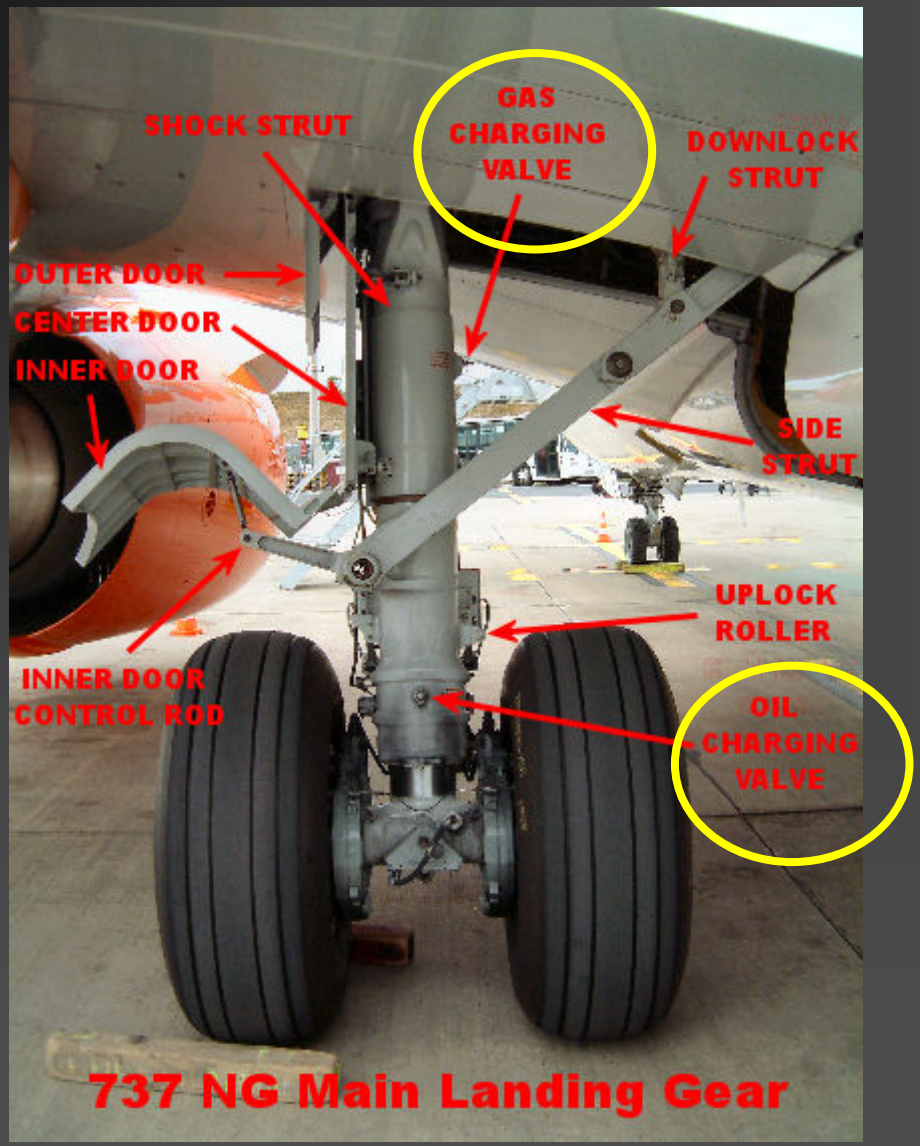
- Support the weight of the aircraft while it is on the ground
- Take off and land the aircraft safely
- Absorb landing and taxiing shocks
- Steer the aircraft
- Stop the aircraft

Main landing gear

Operation of Shock Strut



Main landing gear servicing



Nose landing gear

Forgetting to remove the safety pin is a contributing factor in LG failure

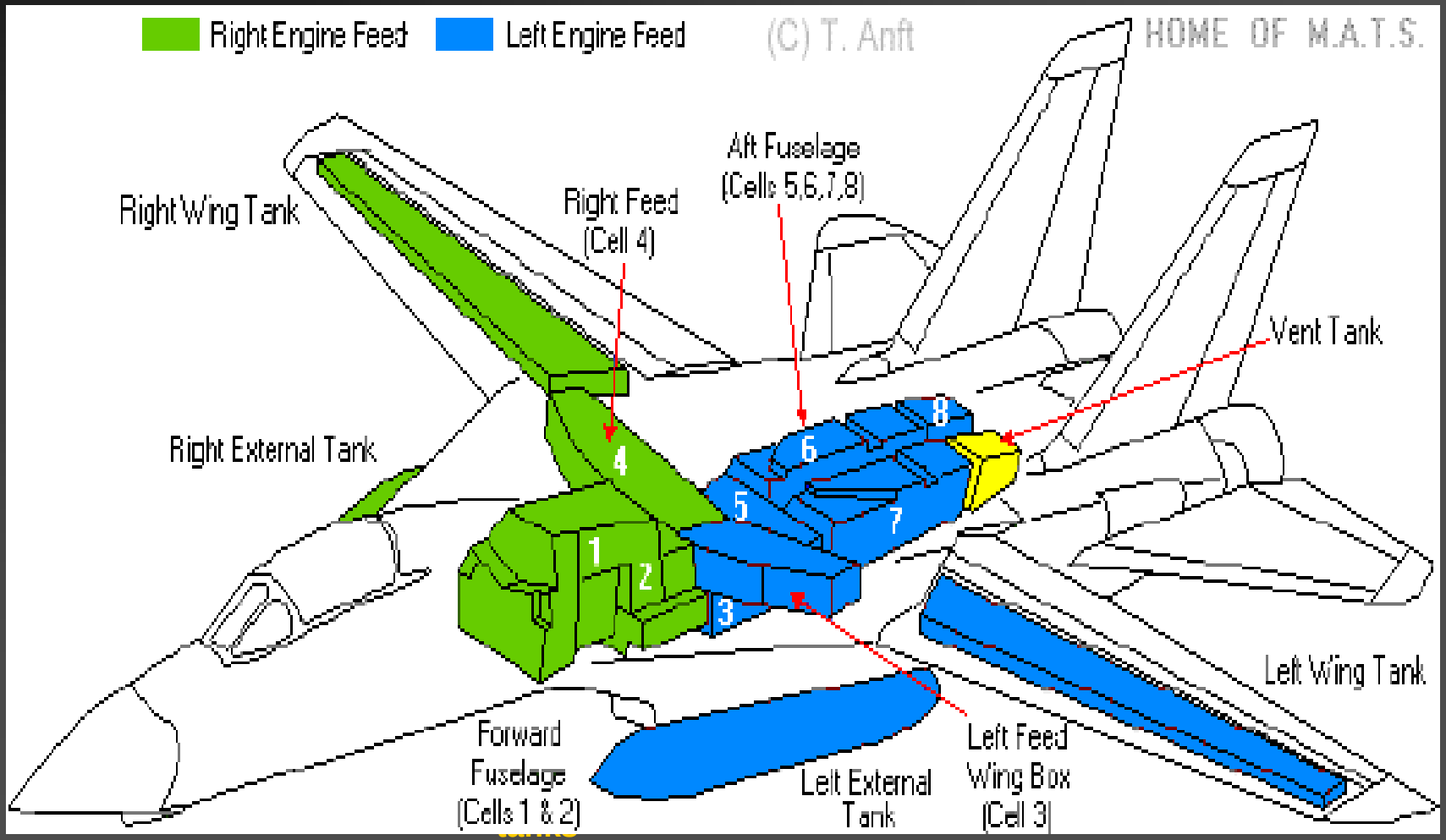
AIRCRAFT FUEL SYSTEM

Aircraft Fuel System

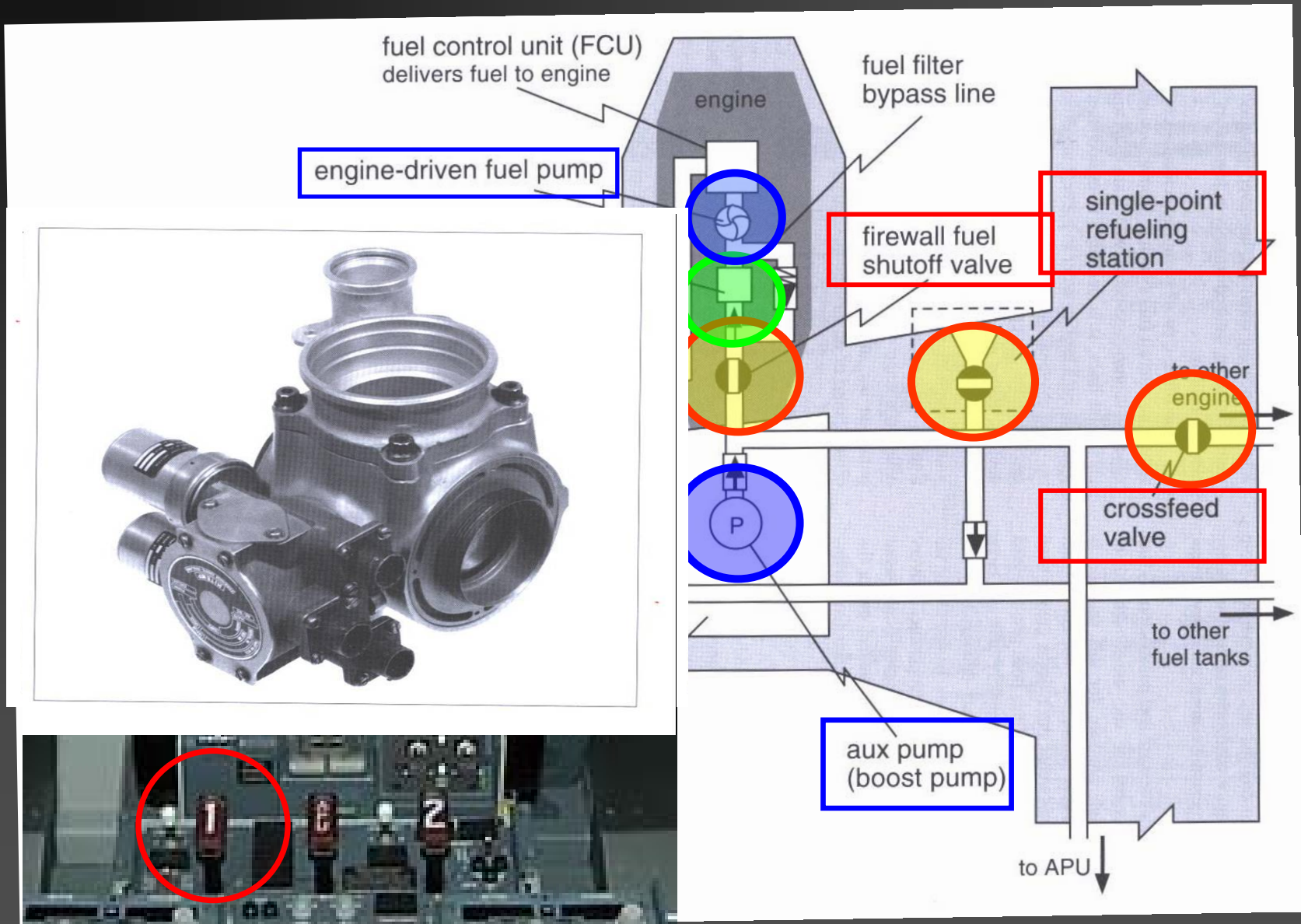
Provides continuous flow of fuel to engine in all flight conditions. Main components are:

- Fuel tanks
- Fuel Pumps and valves
- Fuel Filters
- Fuel heaters
- Fuel instruments

Fuel tanks

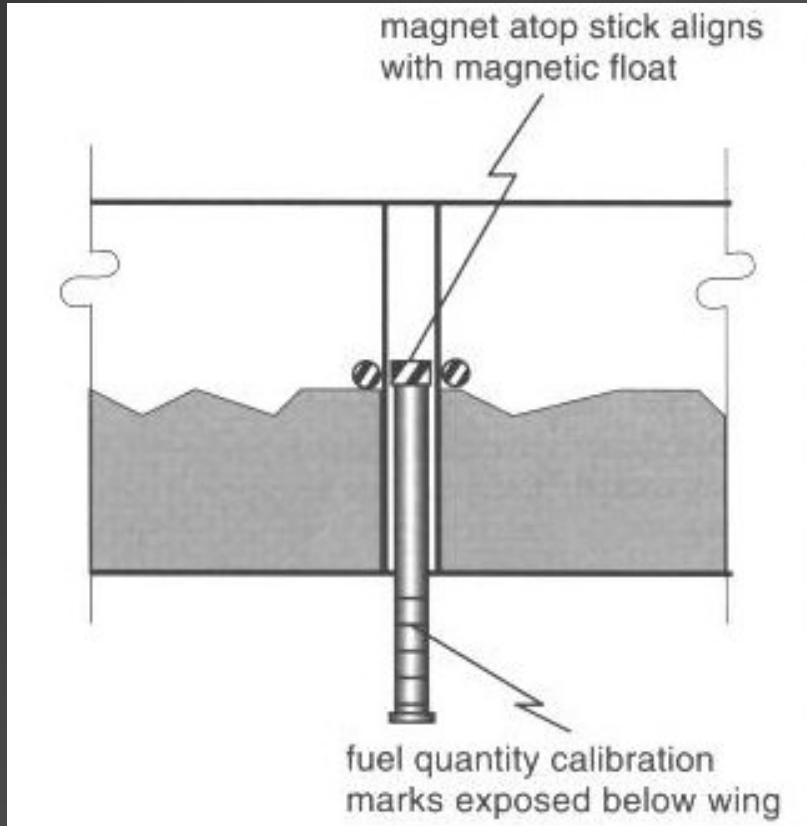

Right Engine Feed
Left Engine Feed
(C) T. Anft
HOME OF M.A.T.S.
Right Wing Tank
Right Feed
(Cell 4)
Aft Fuselage
(Cells 5,6,7,8)
Vent Tank
Right External Tank
4
6
8
5
7
1
2
3
Left Wing Tank
Forward
Fuselage
(Cells 1 & 2)
Left External
Tank
Left Feed
Wing Box
(Cell 3)

Aircraft Fuel System Components



Fuel Quantity Indicator

Magnetic Fuel Quantity Stick

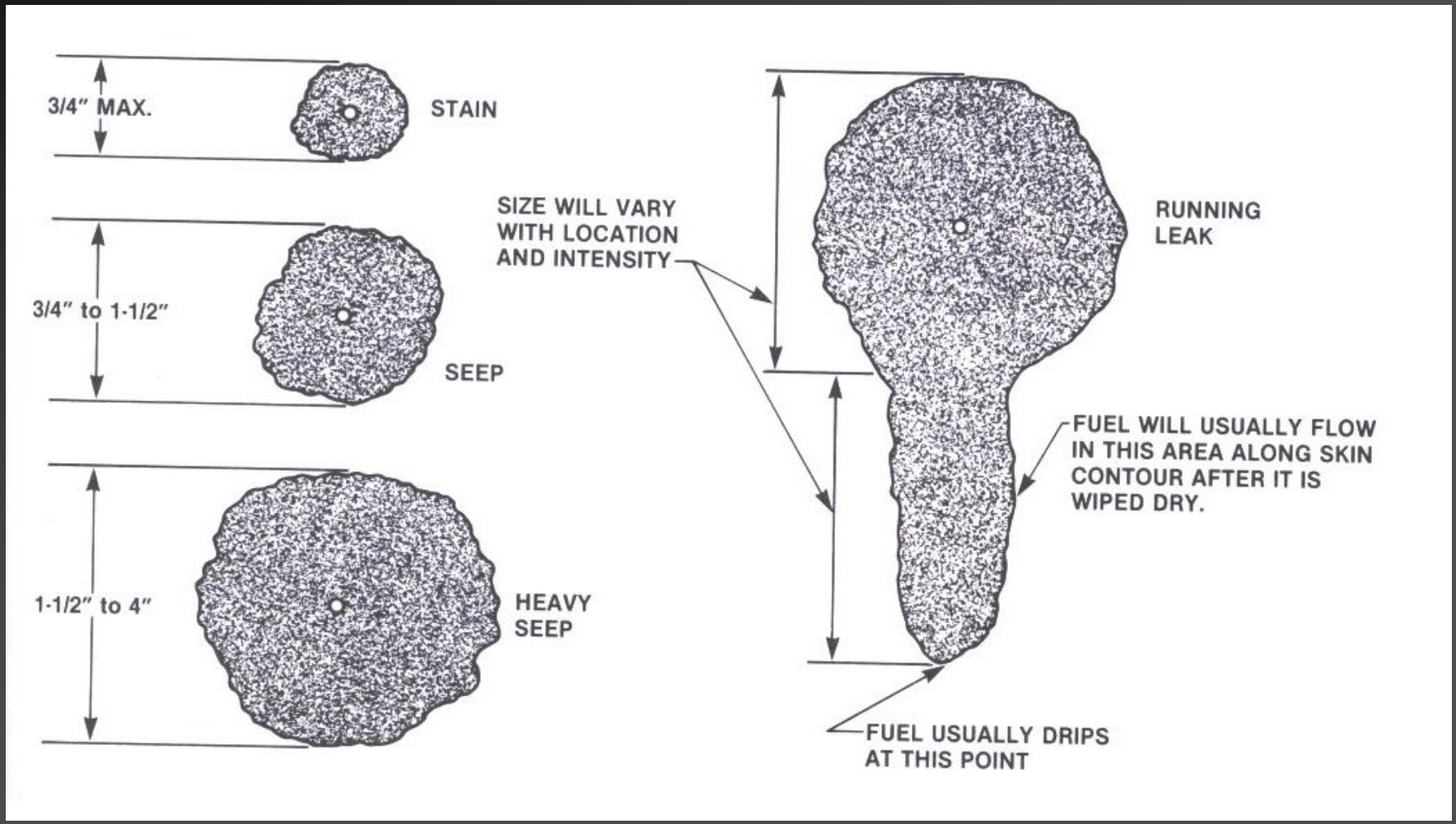


To manually check fuel quantity, stick is unlocked and lowered from bottom of wing. Fuel quantity is determined from calibration marks exposed under wing.

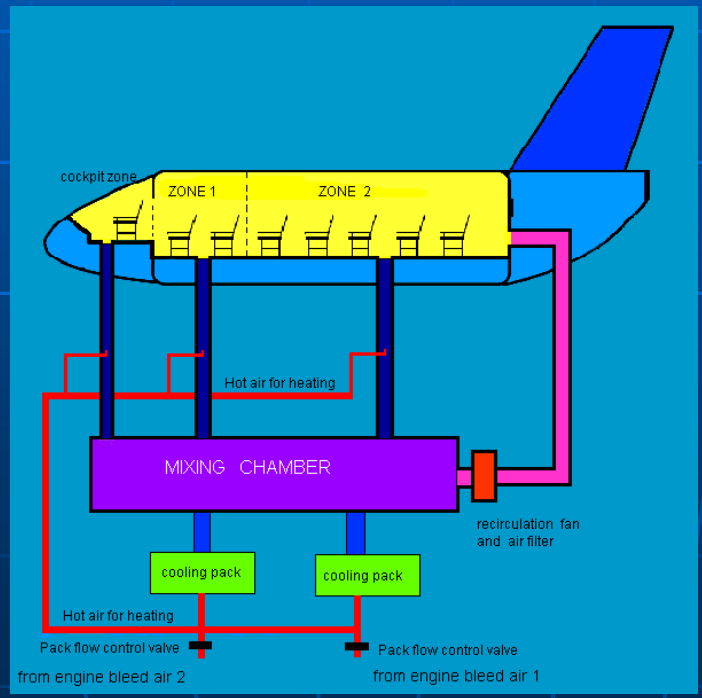
Fuel system troubles

- **Contamination**
  - *Water*
  - *Mixing with other types of fuel*
  - *Foreign particles*
  - *Microbial growth*
  - *Sediment*
- **Leakage**

Fuel leakage classification



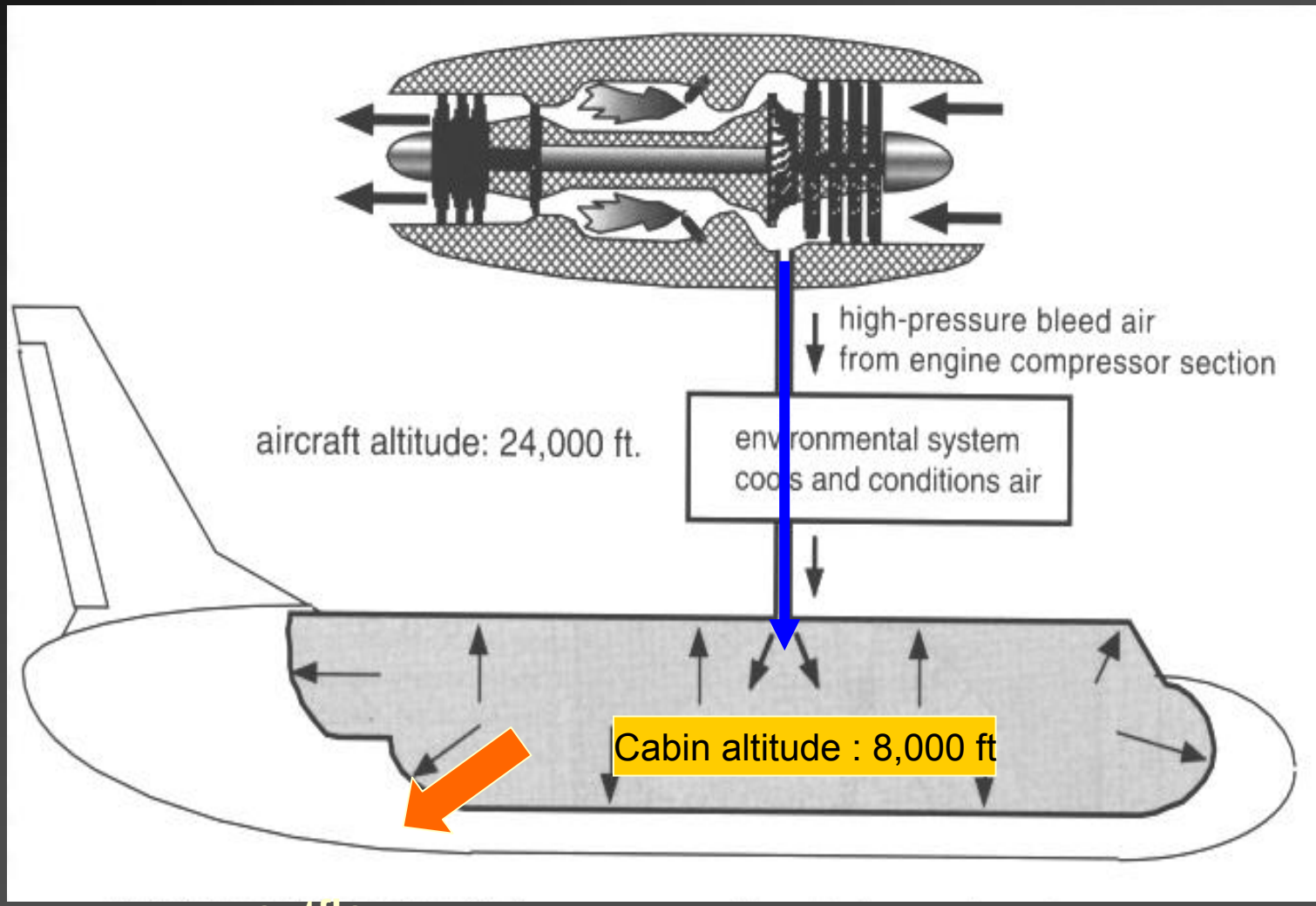
AIRCRAFT CABIN ATMOSPHERE (ENVIRONMENTAL CONTROL) SYSTEM



Functions of cabin pressurization system

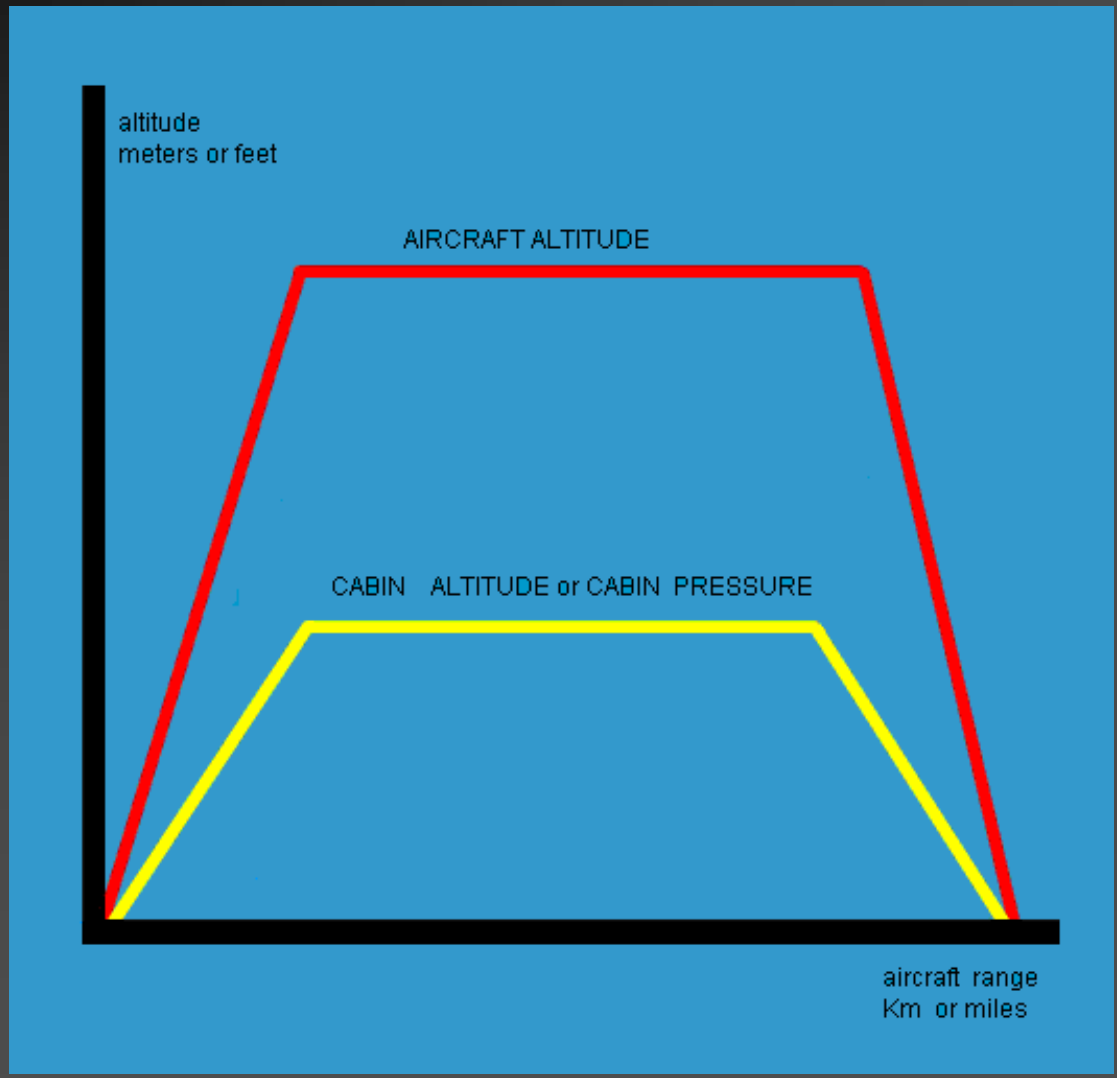
- Automatically maintain a maximum cabin altitude of about 8 000' at the aircraft's maximum designed cruising altitude
- Prevent rapid changes of cabin altitude regardless of rate of climb or descent
- Reasonably fast fresh air exchange to eliminate odors and remove stale air

Cabin pressurization



outflow

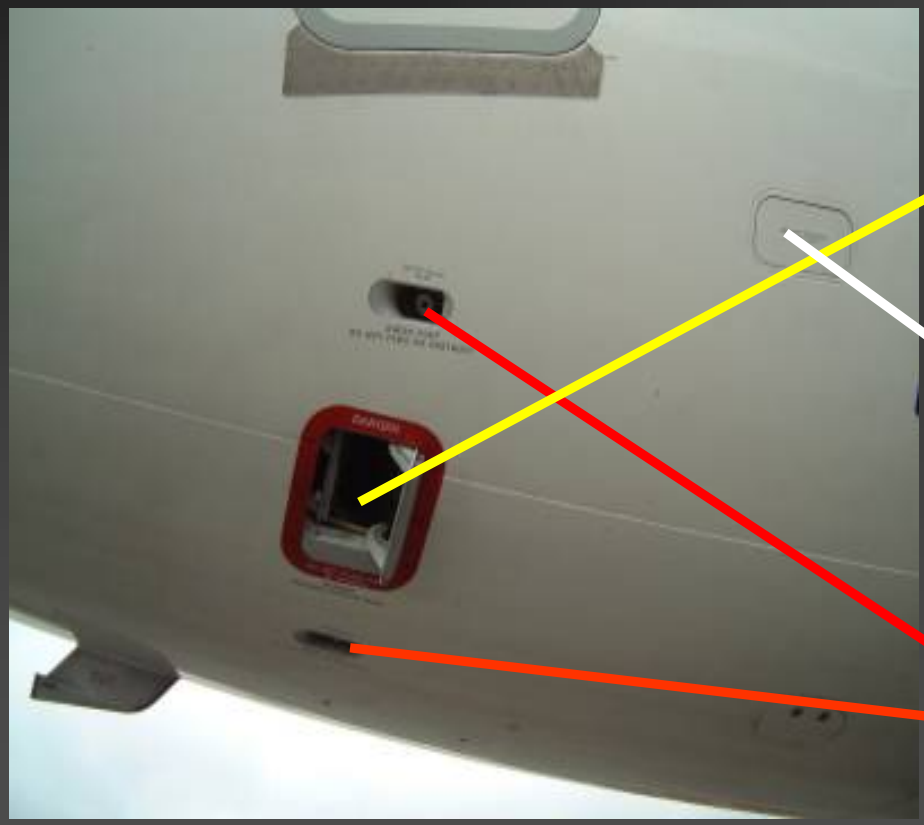
Cabin altitude vs. aircraft altitude



System components

Neg. Pres.
Safety valve

Pressurization valves on aircraft



Outflow valve

Neg. Pres.
Safety valve

Pos .Pres.
Safety valves

Cabin pressure indicators

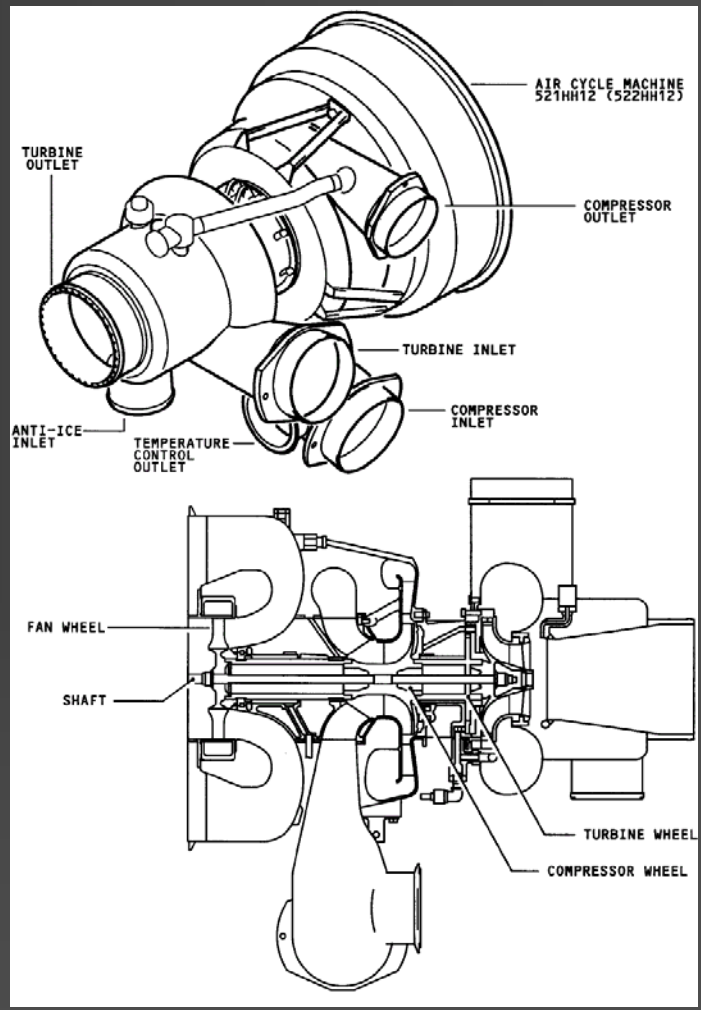
Air conditioning system

- Maintain a comfortable cabin temperature throughout al conditions of flight
- Control cabin humidity to assure passenger comfort
- Prevent window fogging
- Provide cooling for avionics

Types of air conditioning systems

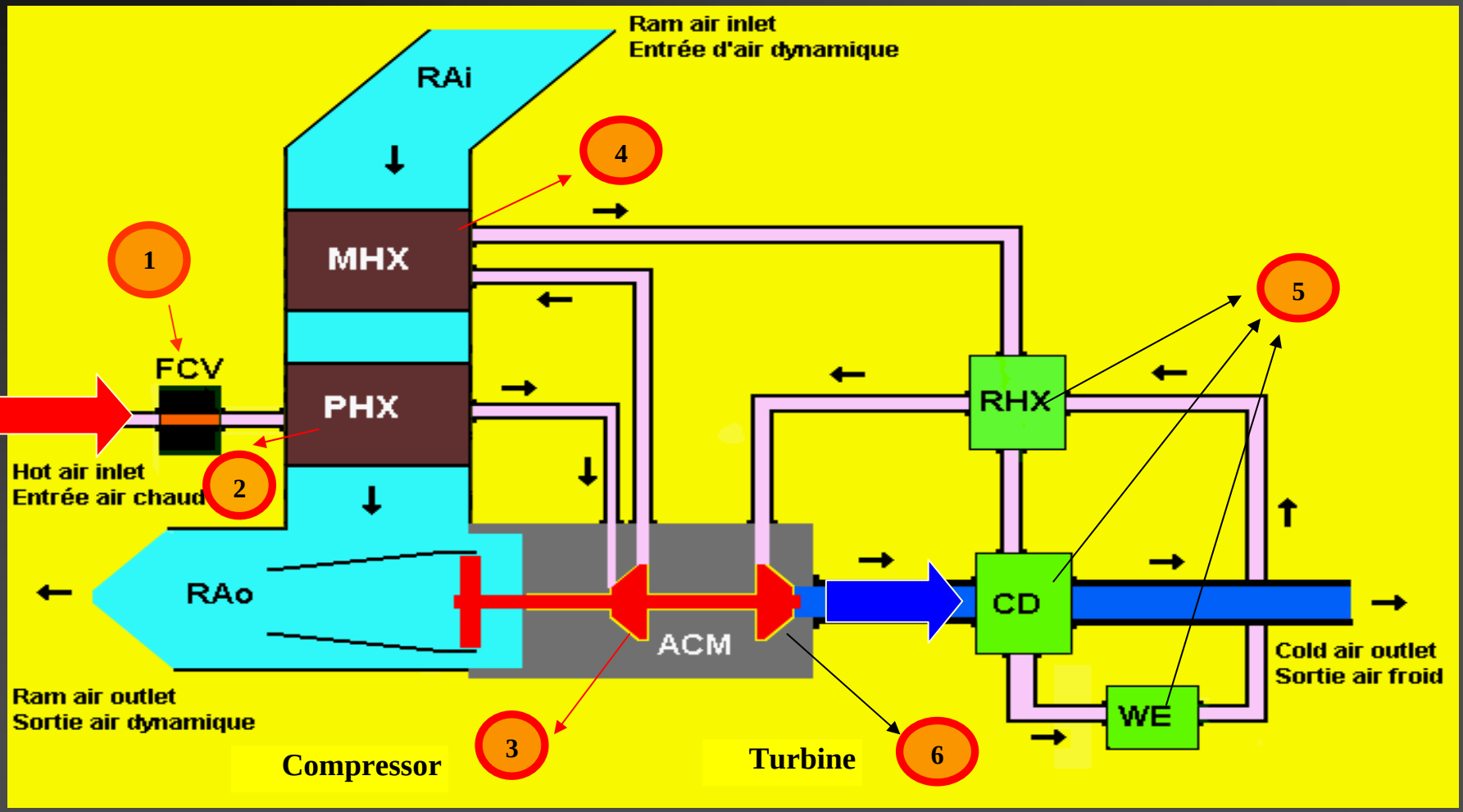
There are two types of air conditioning system used in aircraft.

- Air cycle machine (ACM) system
- Vapor cycle system



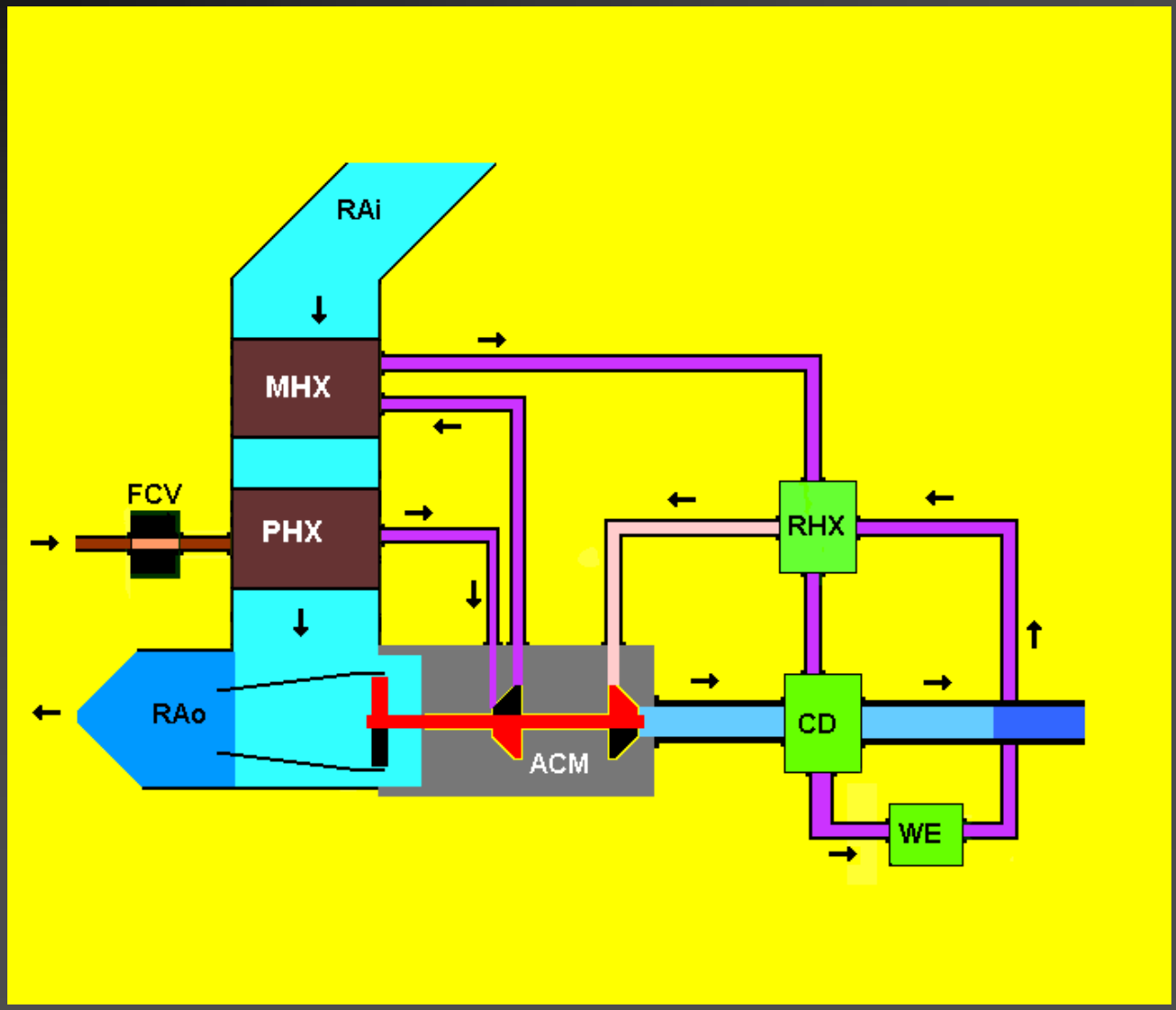
Air Cycle Machine

Operation of air cycle machine

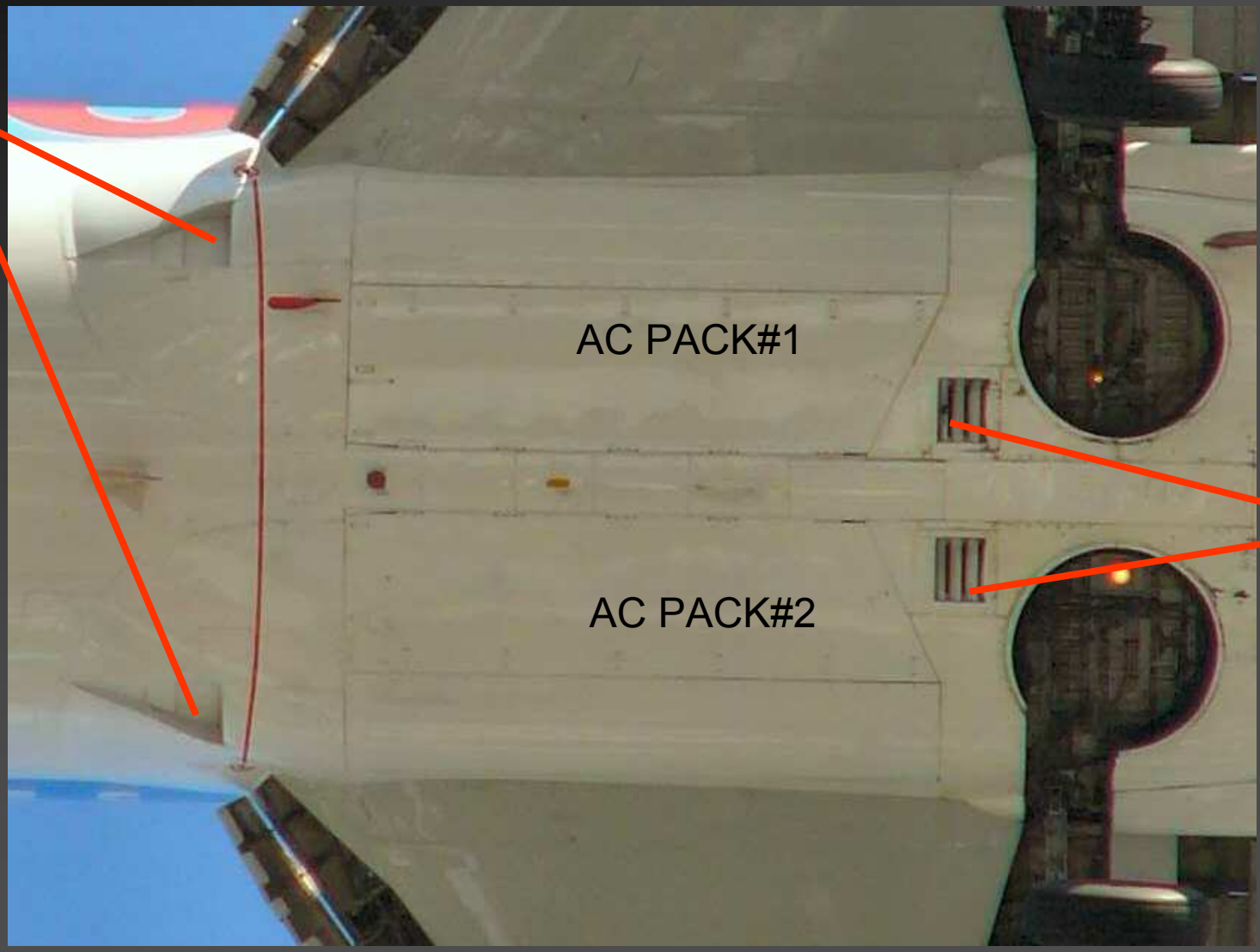


FVC :Flow Control Valve
PHX: Primary Heat Exchanger
MHX : Main Heat Exchanger
RHX: Reheater
CD : Condenser
WE: Water extractor

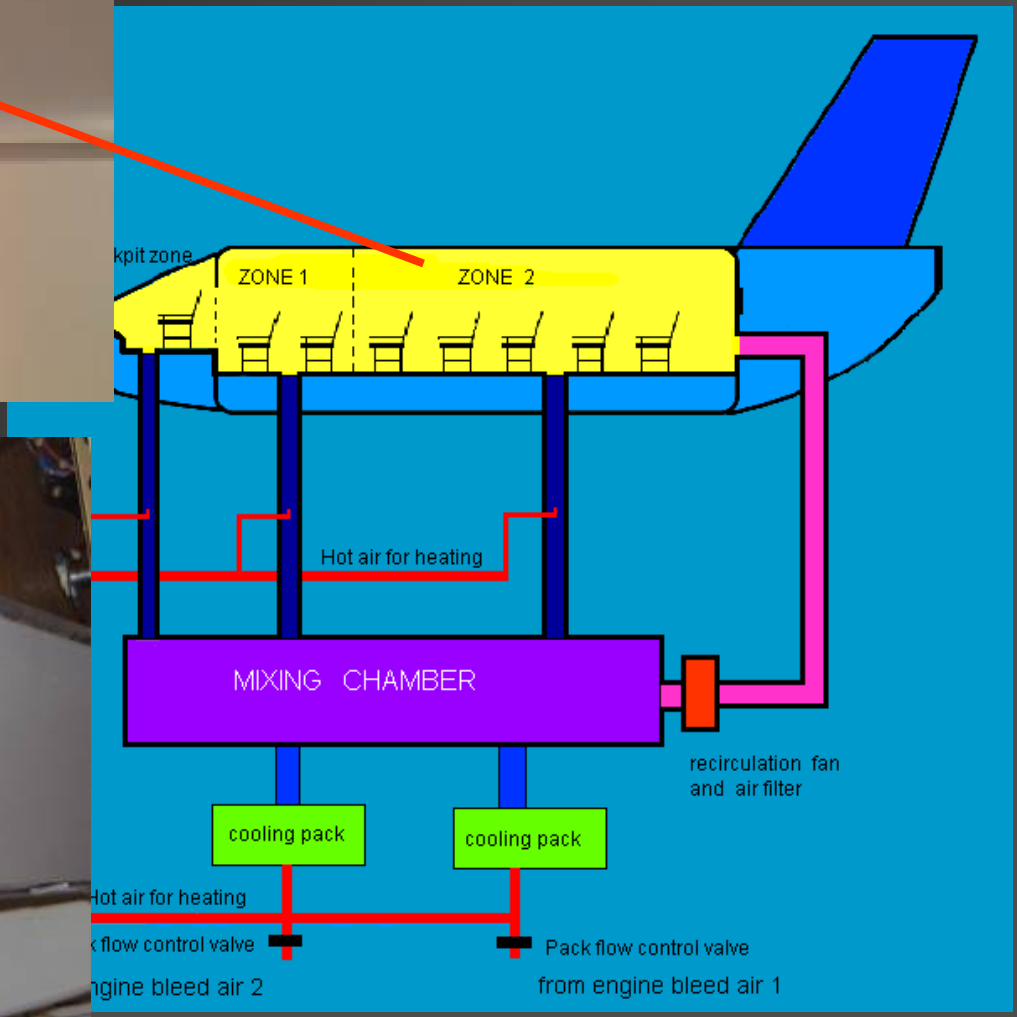
Animation of operation of ACM system



Air conditioning packs/ram air inlets

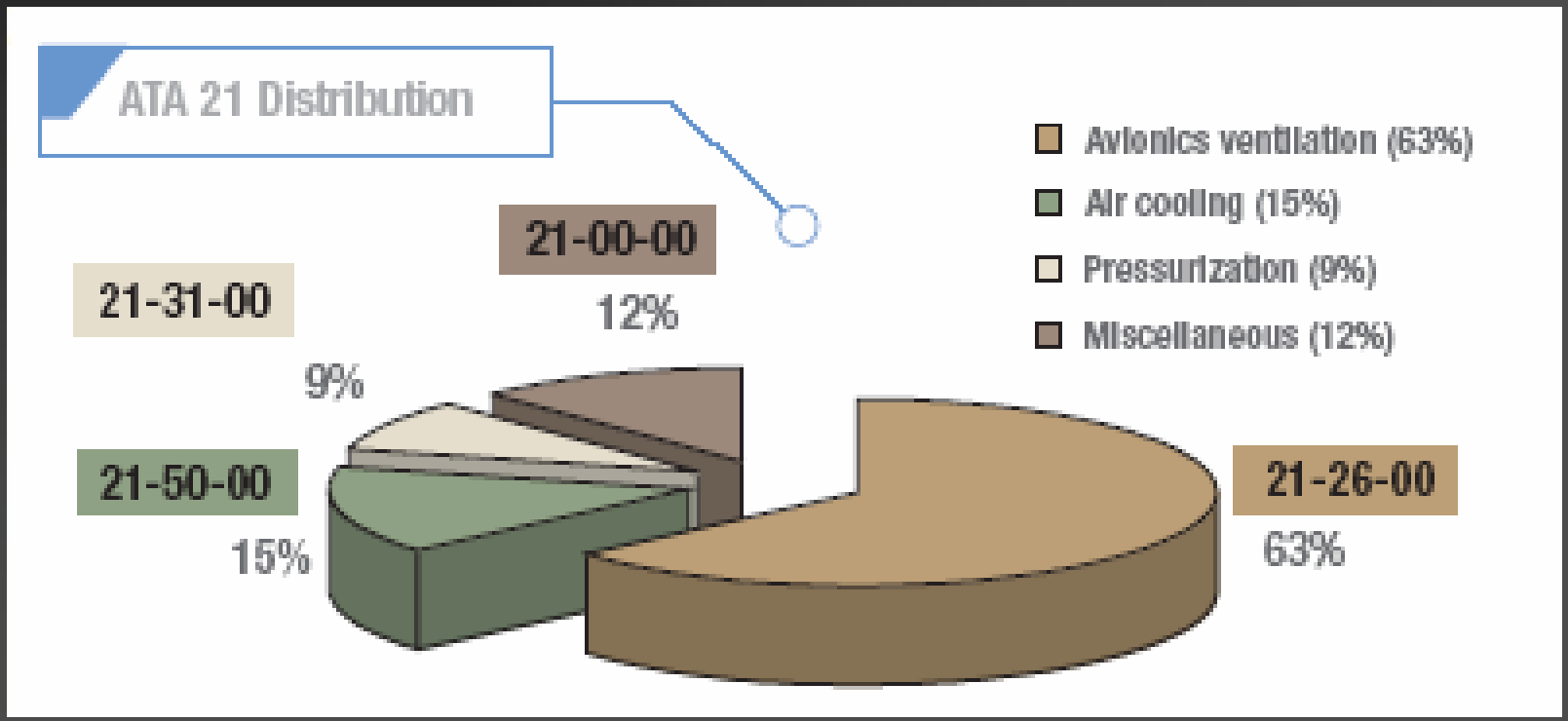


Distribution of conditioned air

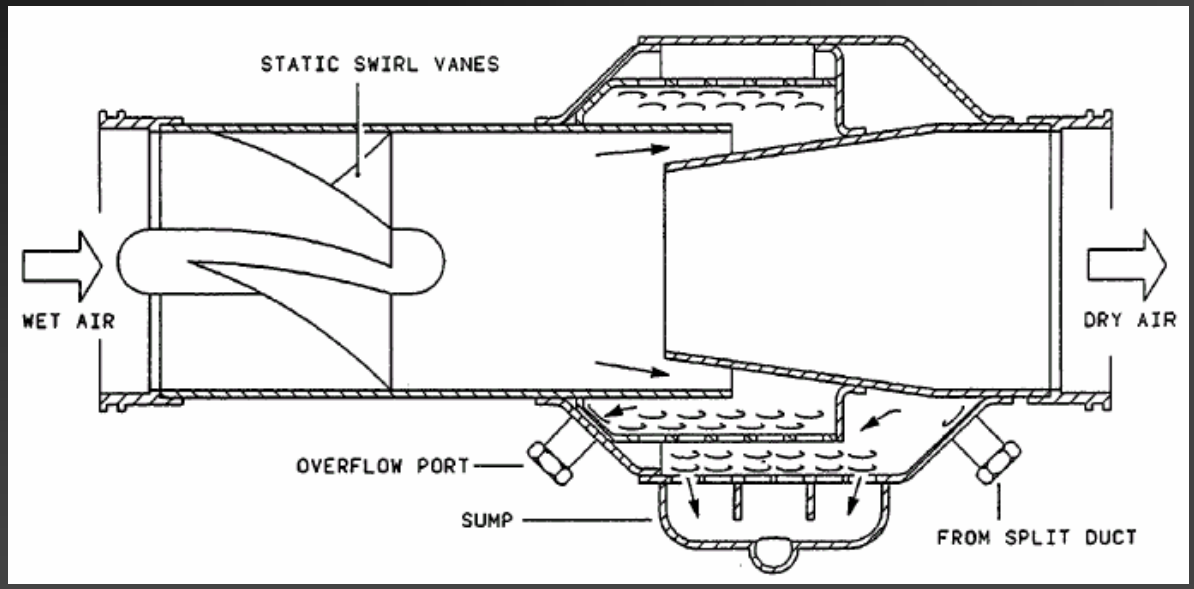


Environmental system failures

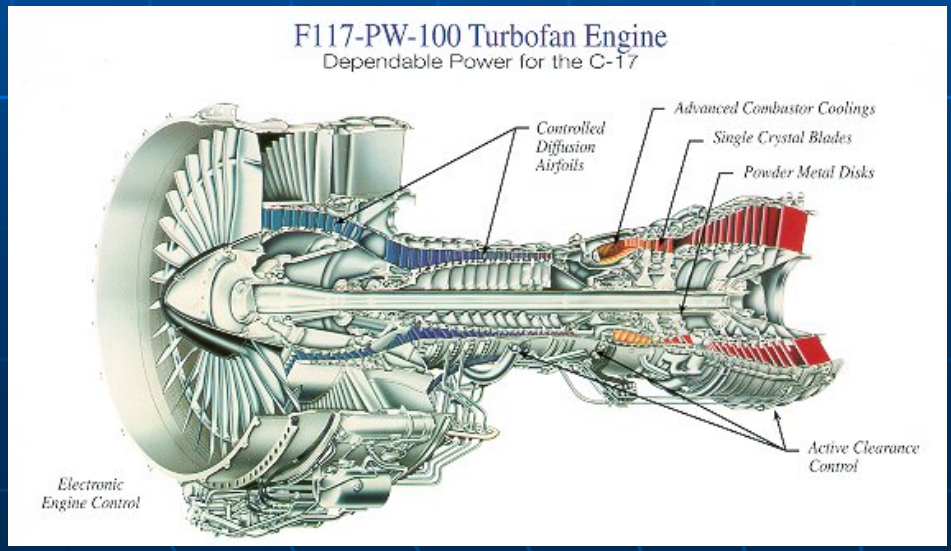
Between 2001 and 2004, 14% of in-flight interruptions have been attributed to environmental control system. They can be further divided as shown in the figure.



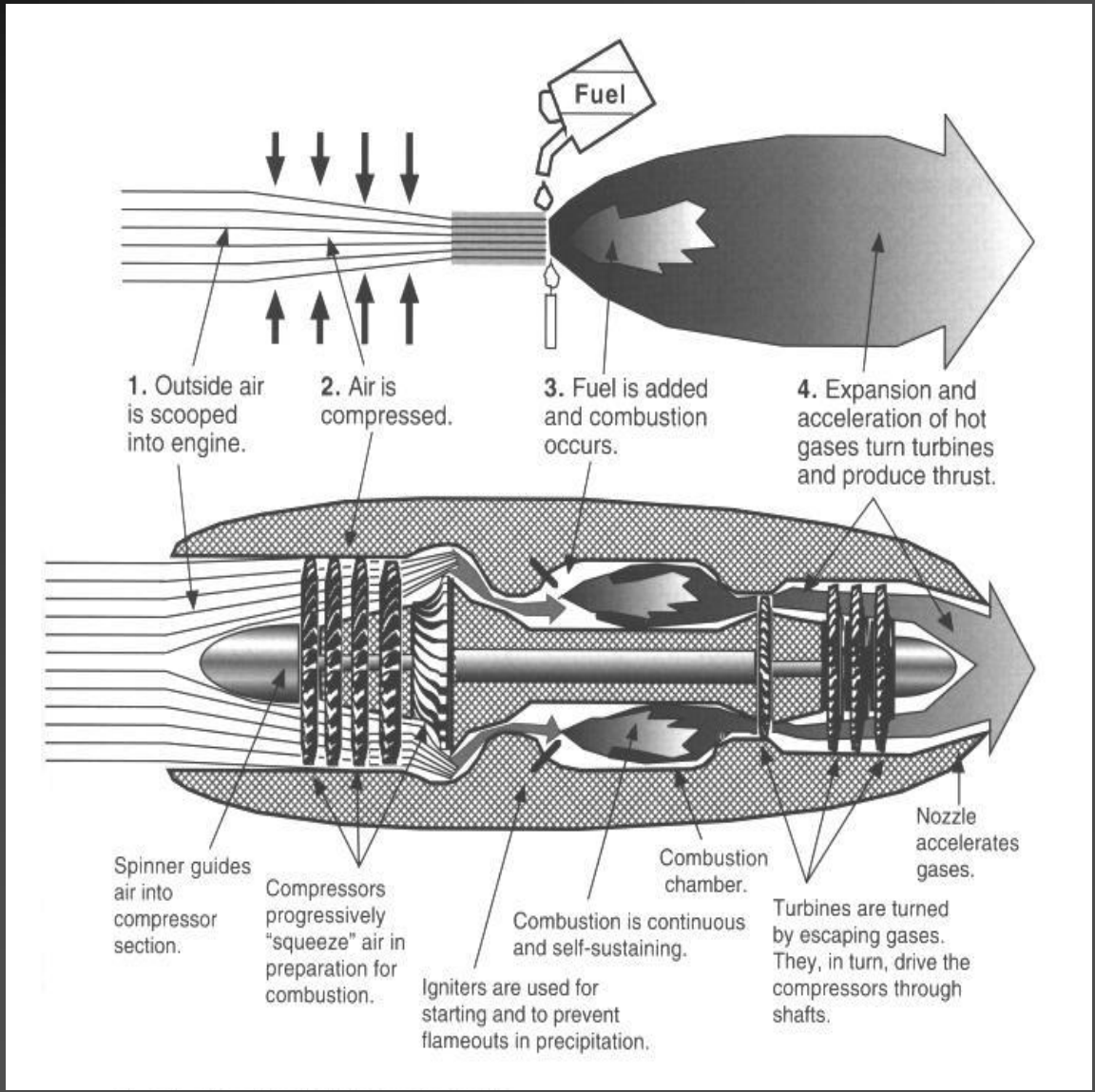
Water separator is the major problematic component with the highest failures.



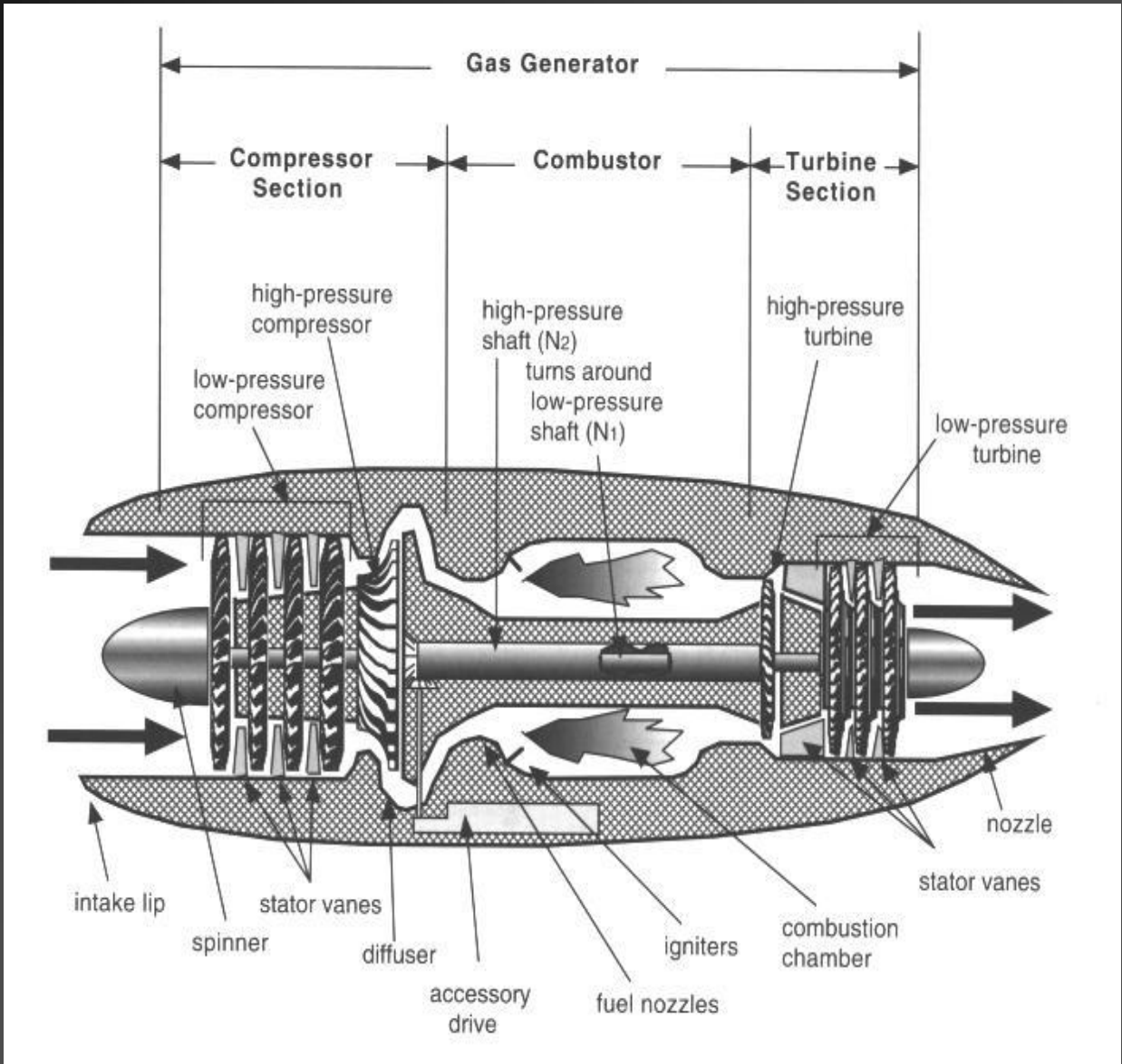
AIRCRAFT ENGINES



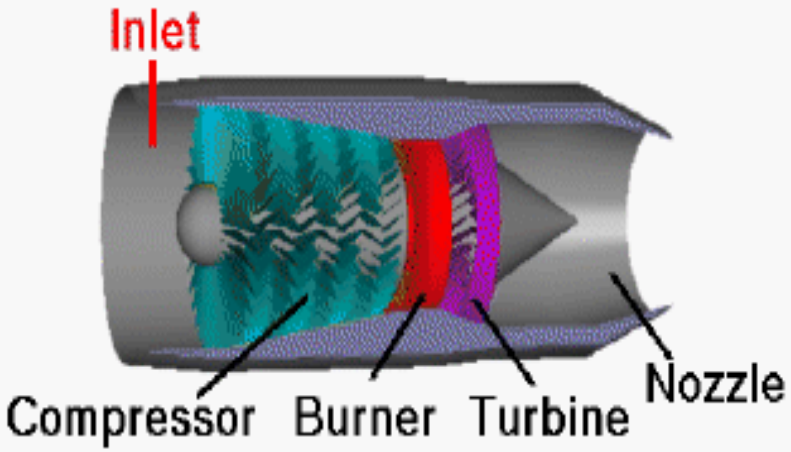
Operation of a turbine engine



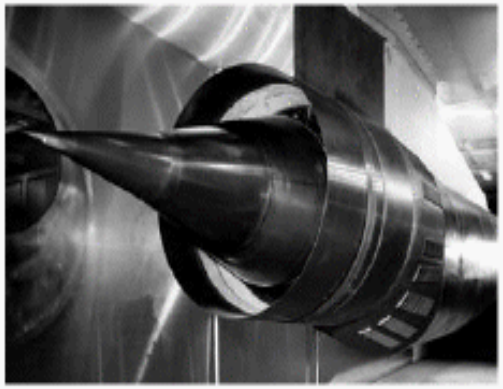
Turbine engine components



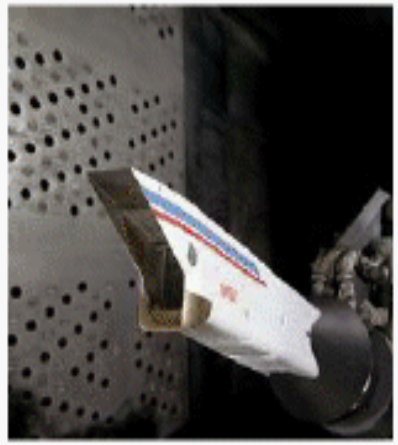
Air inlet



Subsonic

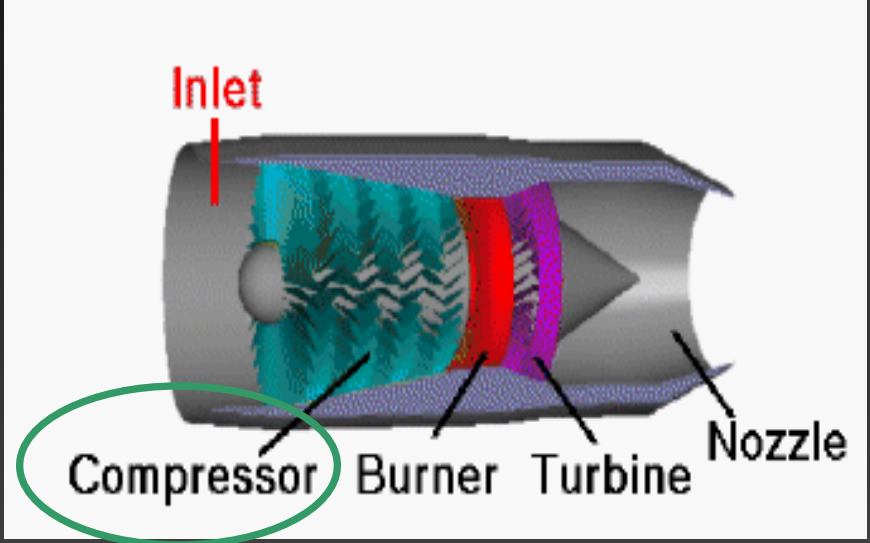


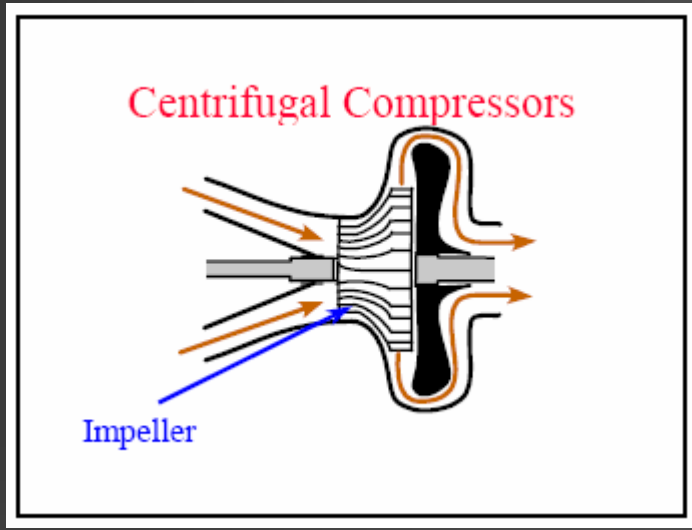
Axisymmetric Supersonic

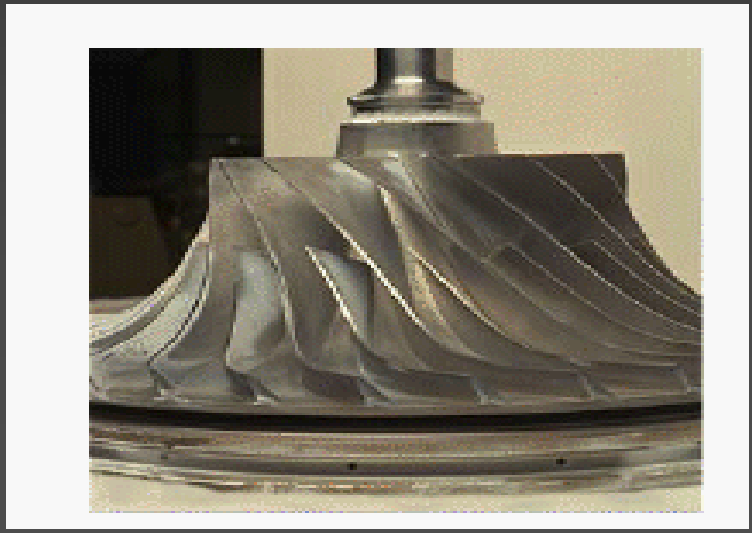


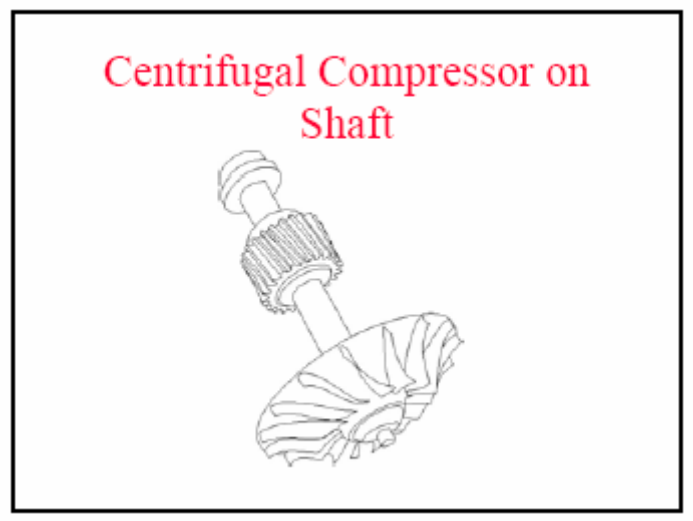
Rectangular Supersonic

Centrifugal Compressor

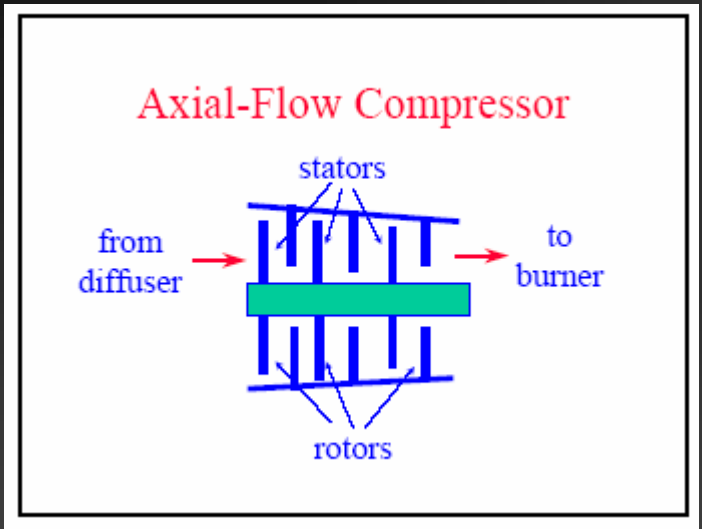


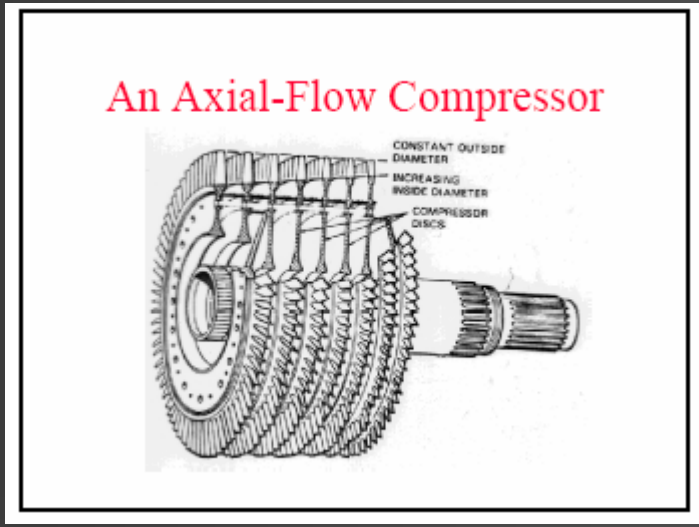






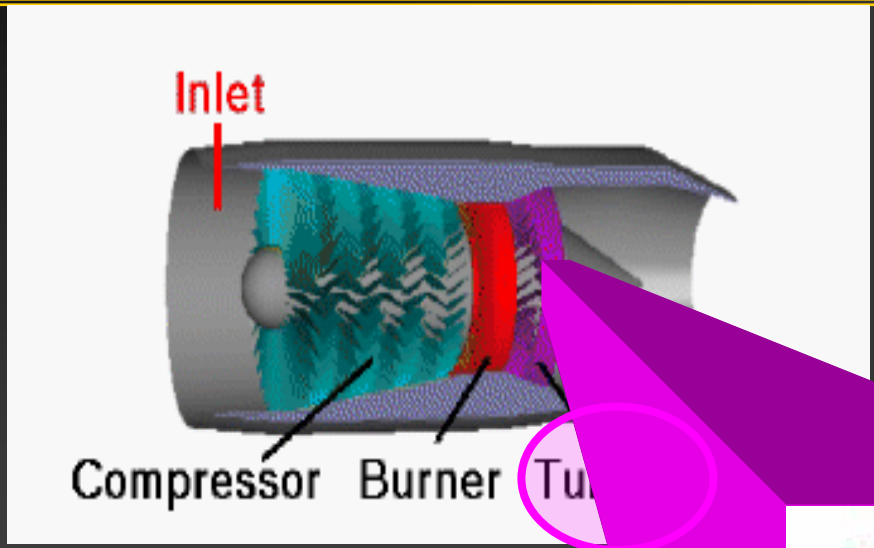
Axial flow compressor

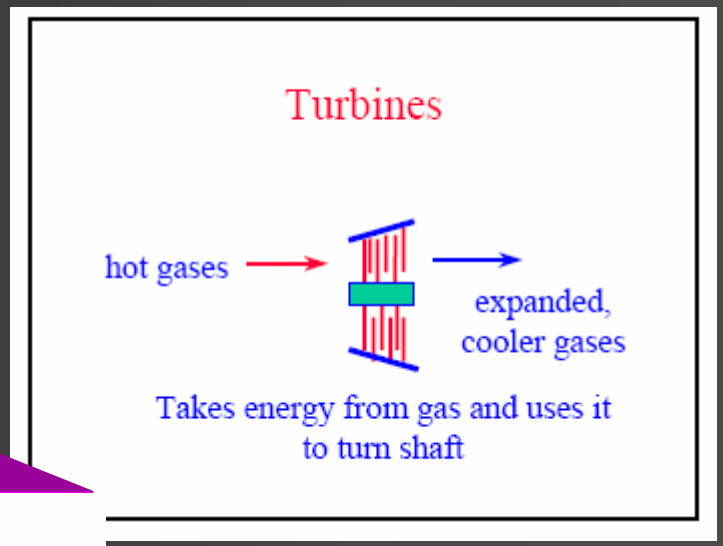


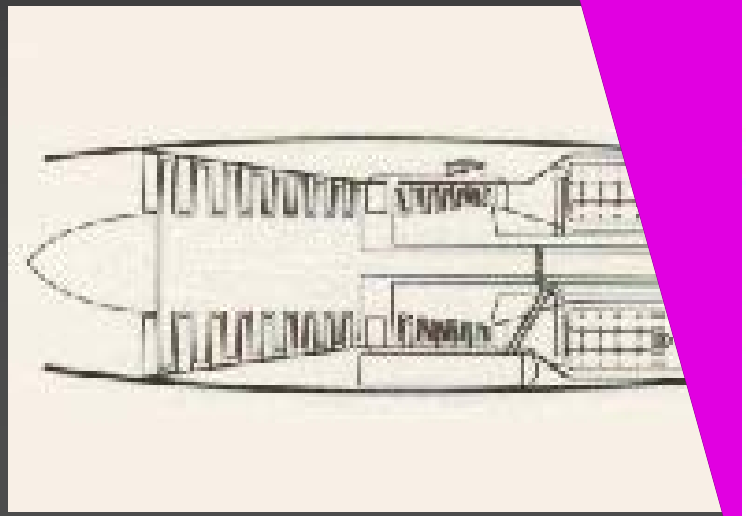


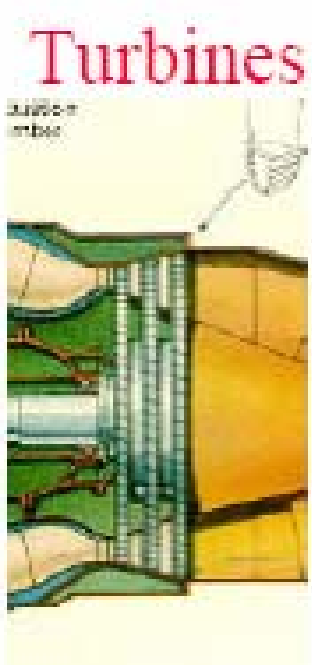
Combustion chamber (burner)

Turbine


Inlet
Compressor
Burner

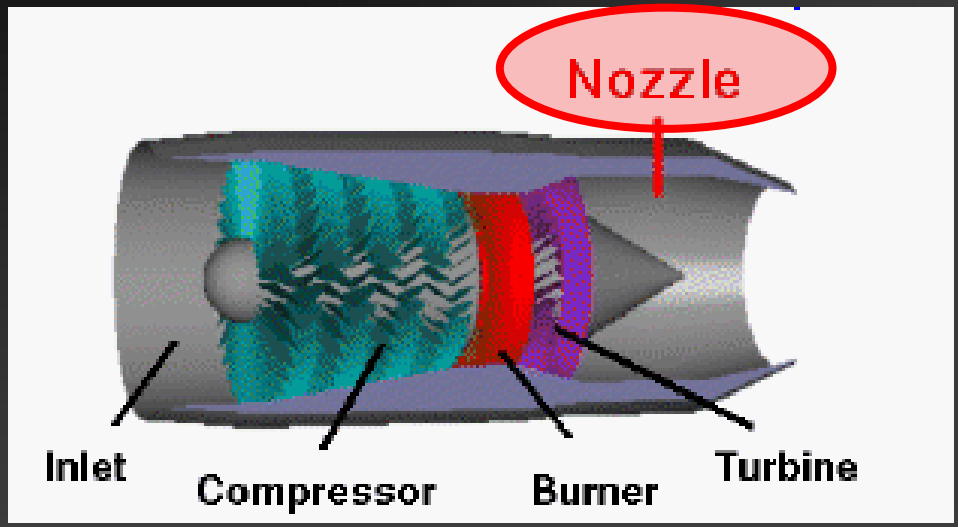

Turbines
hot gases
expanded,
cooler gases
Takes energy from gas and uses it
to turn shaft

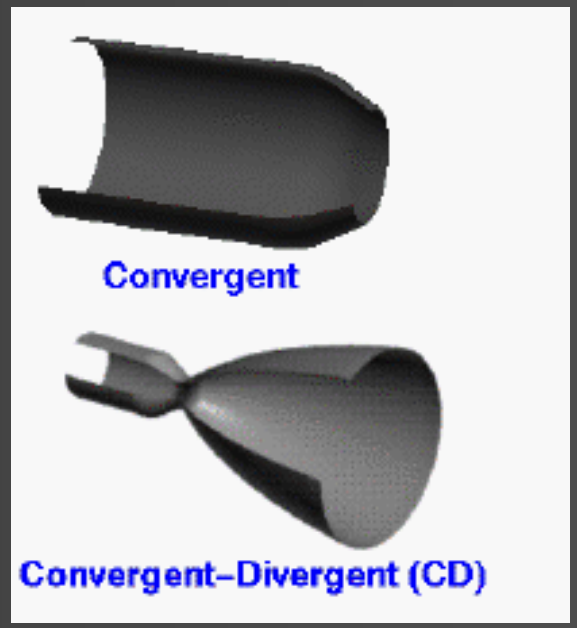



Turbines

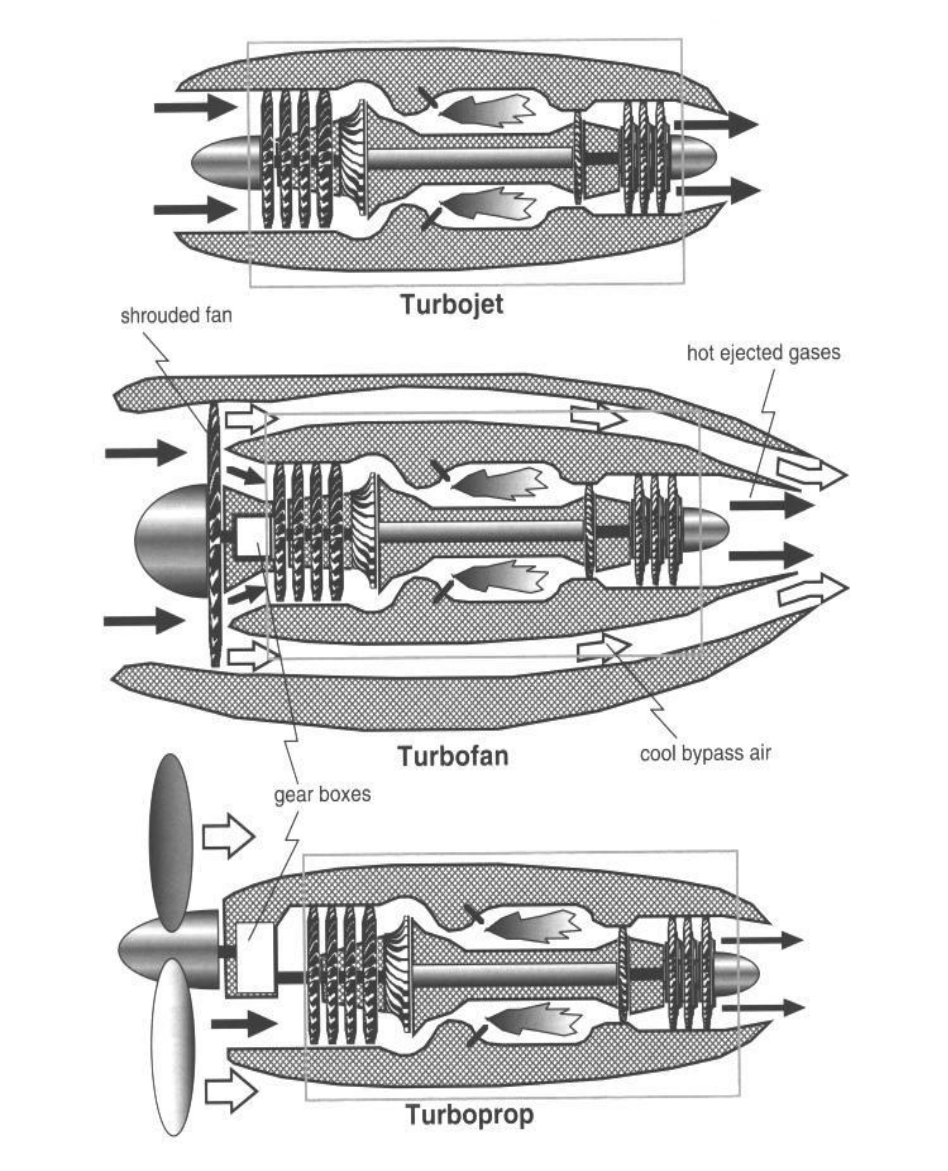

Turbine Blade

Exhaust section (Nozzle)

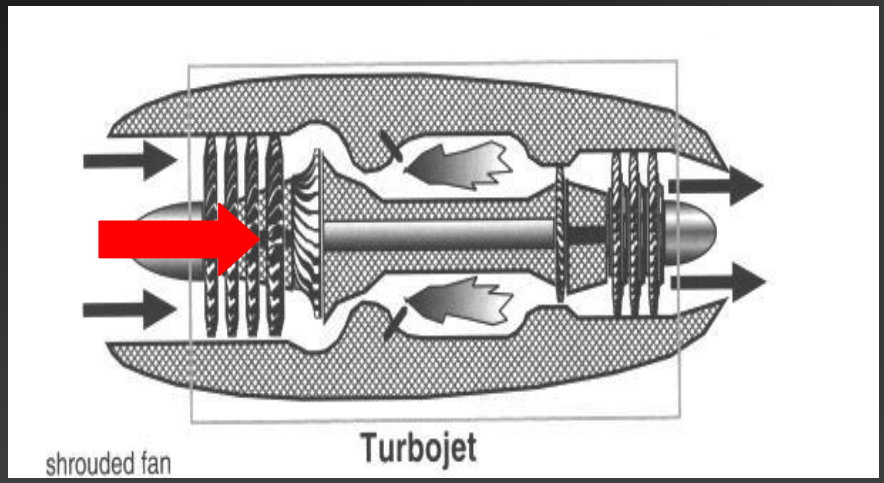


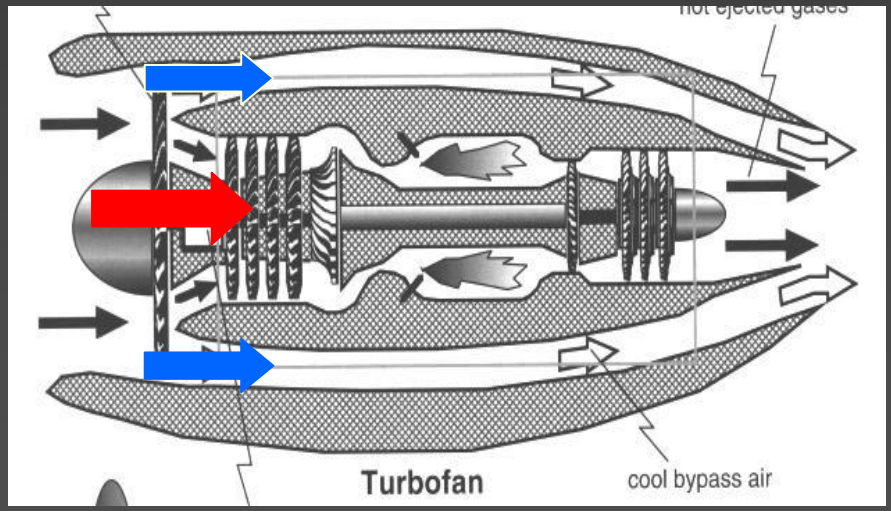


Types of turbine engines



Types of turbine engines

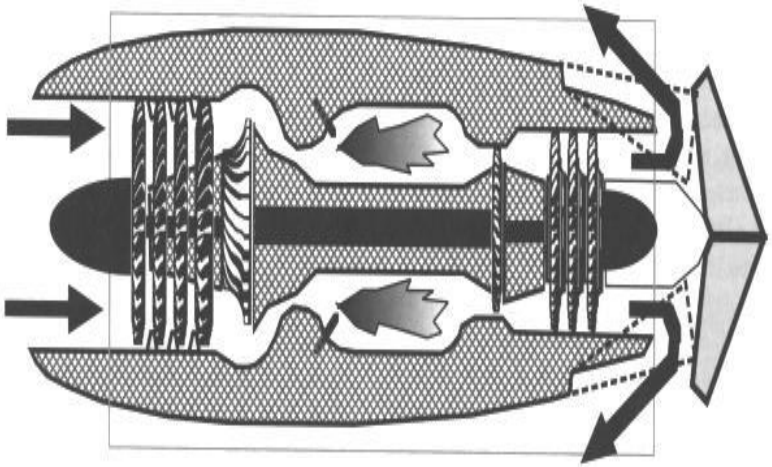




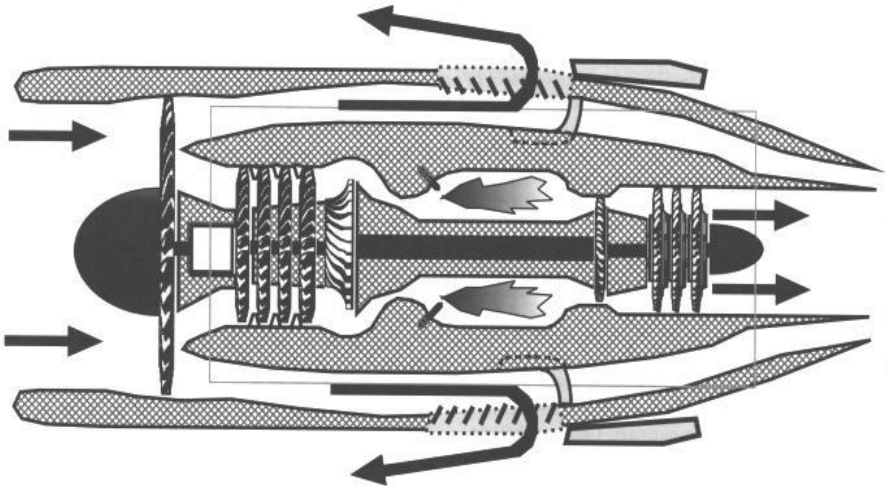
Thrust reversers

- Shorten the routine landing distance
- Reduce the load on the brakes
- Improve braking control on wet, snow-covered or icy runways

Types of thrust reversers



Clamshell reverser



Cascade reverser

Engine Malfunctions

- ***Compressor Surge:***

  A compressor surge (sometimes called a compressor stall) is the result of instability of the air flow through compressor. It is recognized by a loud bang similar to an explosion.

- ***Flame out:***

  A flameout is a condition where the combustion process within the burner has stopped.

- ***Hot Start:***

  During engine start, due to fuel scheduling, strong tail wind, etc. turbine temperature rises to relatively high temperatures. This is known as a hot start.

Engine Malfunctions

- ***Foreign Object Damage:***

  Foreign Object Damage (FOD) is ingestion of objects such as tire fragments, runway debris or animals into the engine.

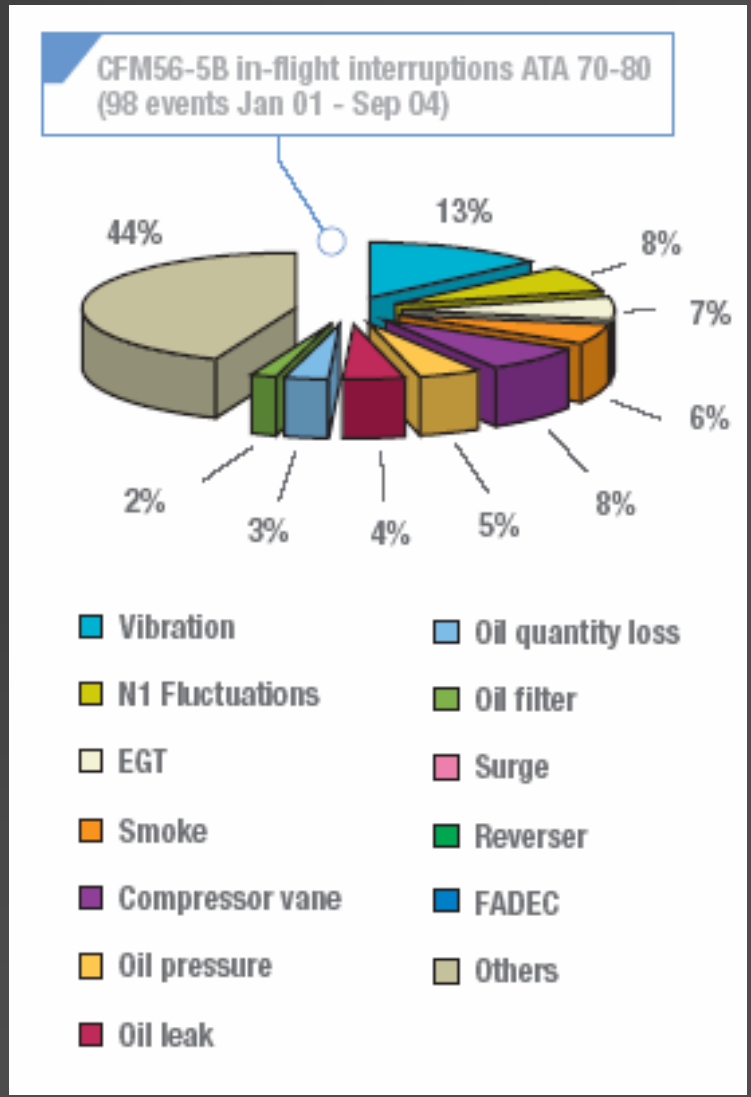
- ***Engine Seizure:***

  Engine seizure describes a situation where the engine rotors stop turning in flight, perhaps very suddenly. The static and rotating parts lock up against each other, bringing the rotor to a halt.

Engine failure causes

Major failure causes of aircraft engine during the last four years:

- Vibration
- Low pressure compressor (N1) problem
- Compressor vane



Engine Maintenance

- **Cold Section**
  - Compressor
  - Foreign Object Damage
- **Hot Section**
  - Combustion chamber, turbine, exhaust
  - Cracks due to thermal shocks
  - Dictates TBO (time before overhaul)

Foreign object damage (FOD)

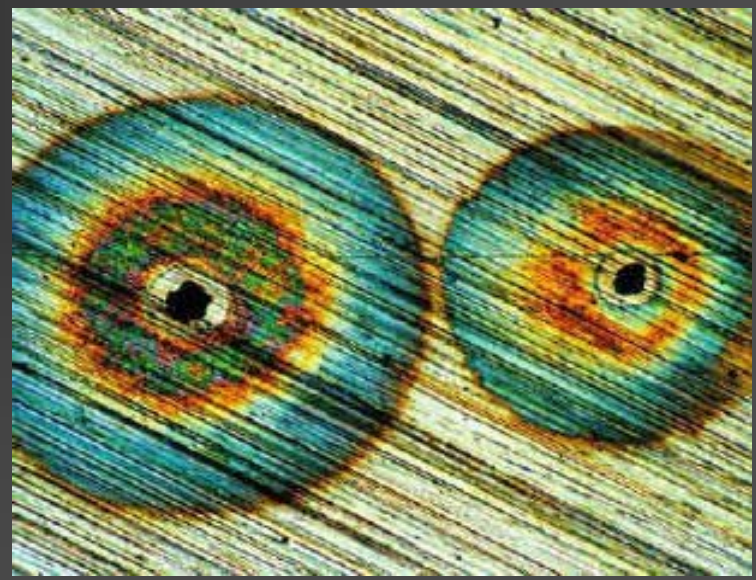
Aircraft corrosion

Most Common Types of Aircraft Corrosion

- Pitting corrosion
- Crevice corrosion
- Intergranular corrosion
- Exfoliation corrosion
- Bimetalic corrosion
- Stress cracking corrosion
- Fretting corrosion

Pitting corrosion

- Pitting corrosion is a localized form of corrosion by which cavities or "holes" are produced in the material.

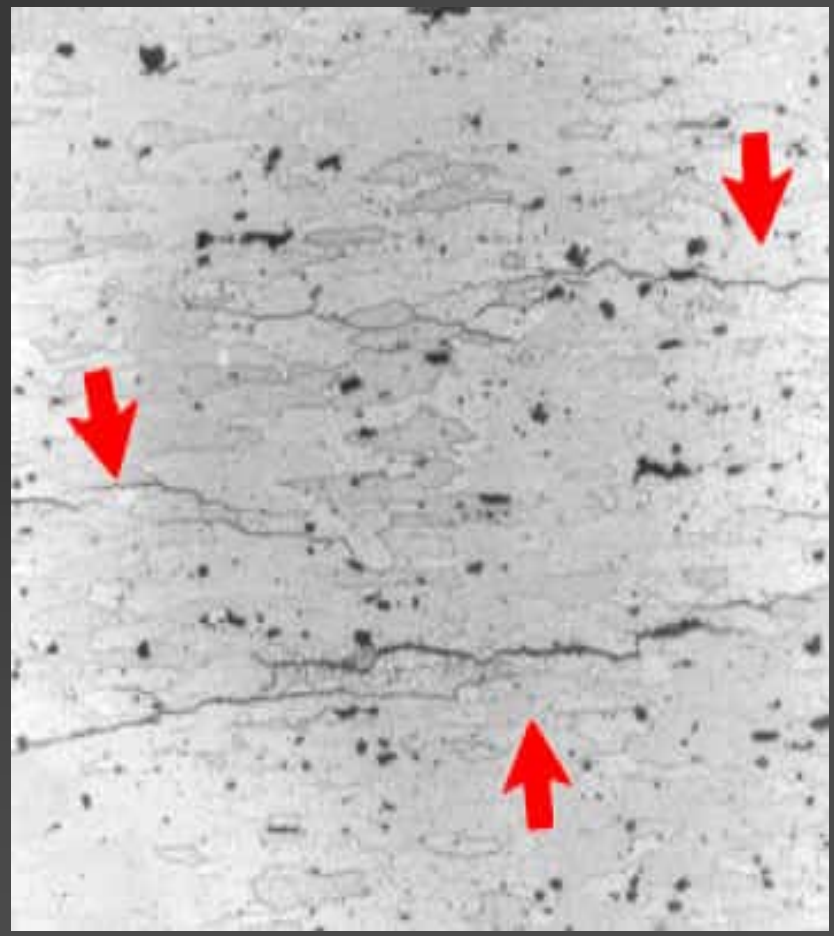


Crevice corrosion

- Crevice corrosion is a localized form of corrosion usually associated with a stagnant solution in crevices (shielded areas) such as those formed under gaskets, washers, insulation material, fastener heads.

Intergranular corrosion

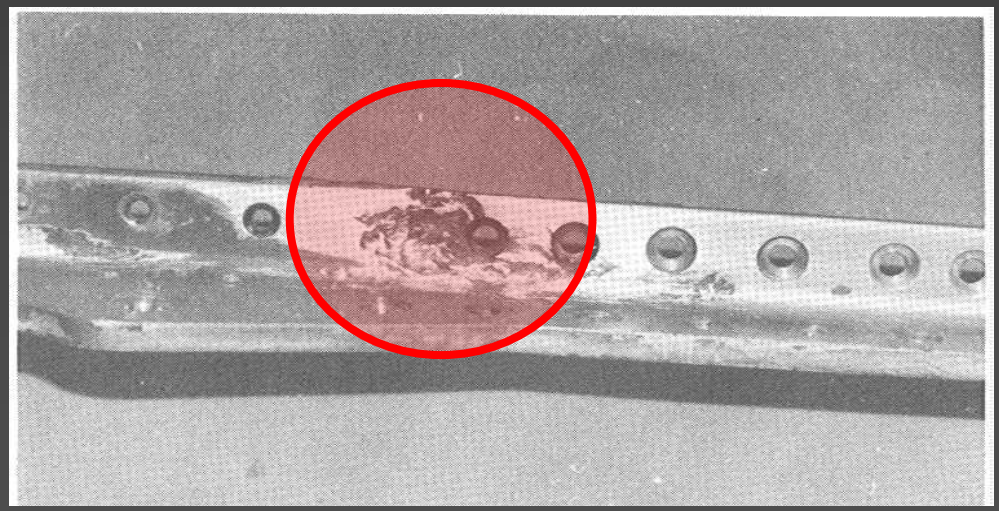
Integranular corrosion is localized attack along the grain boundaries.



Microscopic picture of Inter-granular corrosion of an aircraft component made of 7075-T6 aluminum

Exfoliation corrosion

- It is the severe form of intergranular corrosion.



Bimetalic (dissimilar metal) corrosion

It occurs when two (or more) dissimilar materials are brought into electrical contact under water.

A stainless steel screw in contact with a cadmium plated steel washer.

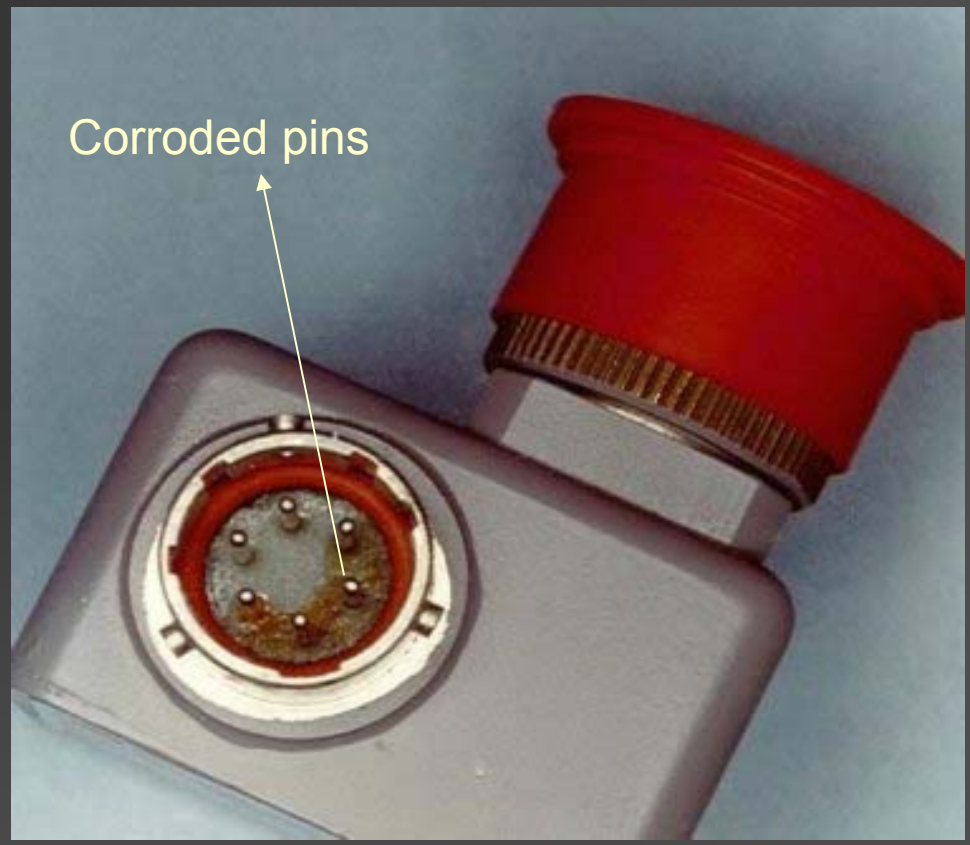
Stress corrosion cracking

- It occurs as the result of the combined effect of sustained tensile stresses and a corrosive environment.

Stress corrosion crack on horizontal stabilizer due to severe metal forming.

Fretting corrosion

- It occurs when two mating surfaces, normally at rest which respect to each one another, are subject to slight relative motion.

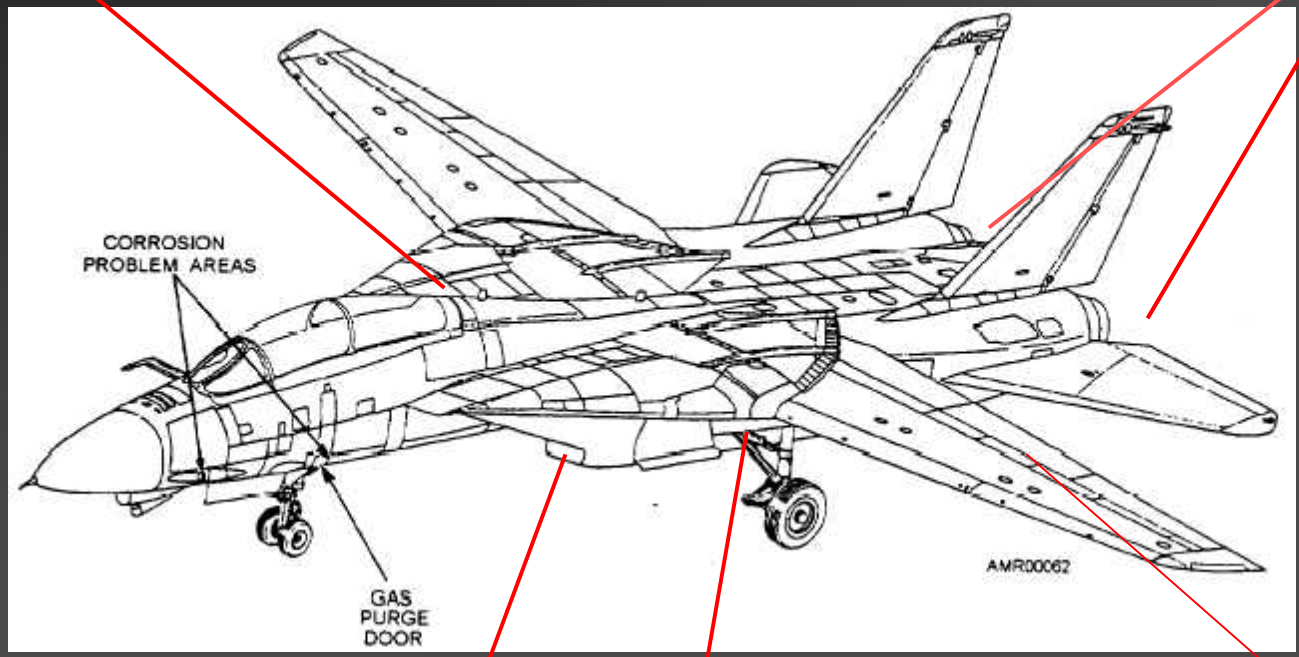


Fretting corrosion of tin-plated electrical connector pins mated with gold-plated sockets in F-16 aircraft main fuel shutoff valve.

Corrosion prone areas

Battery compartment

Exhaust areas



Engine inlet

Wheel well

Flap enclosure

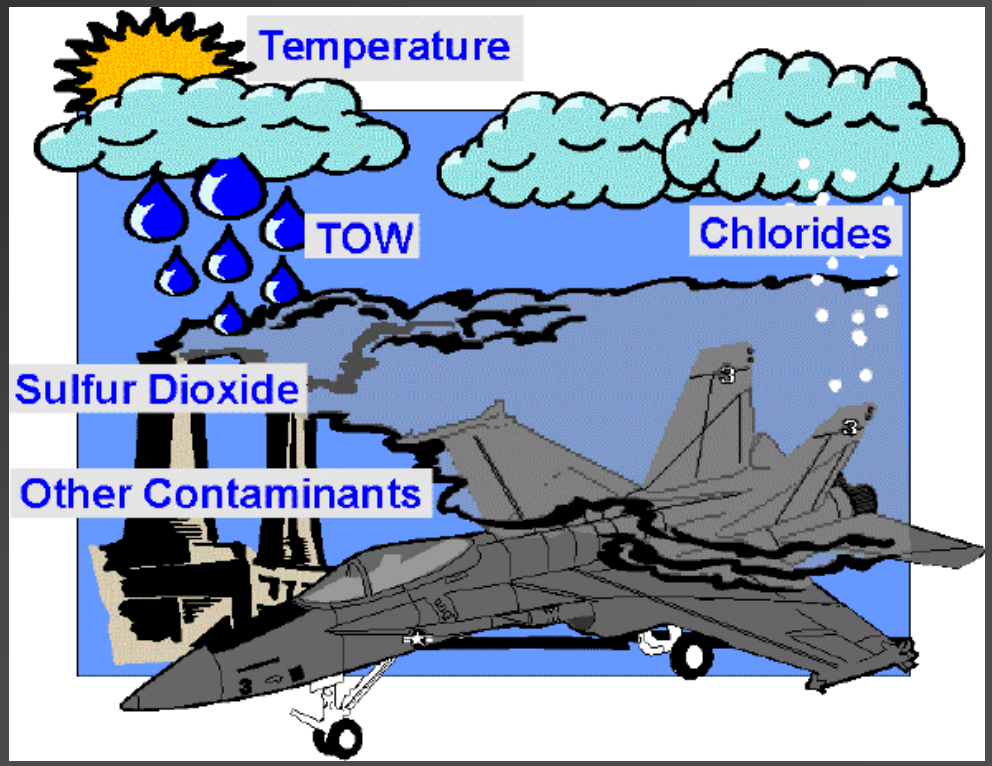
Avionic systems corrosion

Avionics are more prone to corrosion than aircraft because;

- Dissimilar metals are often in electrical contact
- Small amount of corrosion can make equipment inoperative

Effect of Atmospheric Conditions

- Weather conditions
- Atmospheric pollutants



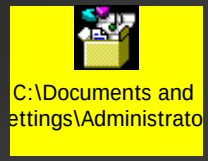
Atmospheric conditions at an air force base in Turkey

PARAMETER	ANNUAL MEAN
Absolute humidity (g/m3)	10.32
Relative humidity (%)	76.00
Temperature (˚C)	14.30
Rainfall (cm)	69.44
Particulates (µg/m3)	70.00
Sulfur dioxide (g/m3)	170.00
Distance to sea (km)	1.50

Protective maintenance against aircraft corrosion

- Washing
- Sealing / Application of inhibitors
- Protective coating (metallic, organic)
- Maintaining water drain valves and drain holes for proper operation
- Training and equipment

Corrosion



AIRCRAFT INSPECTION METHODS

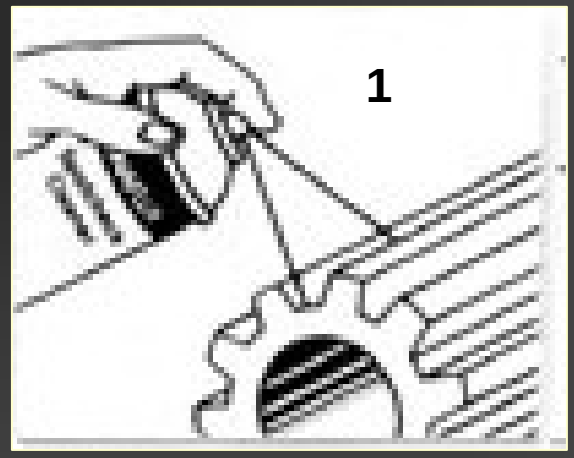
Non-destructive inspection (NDI) methods

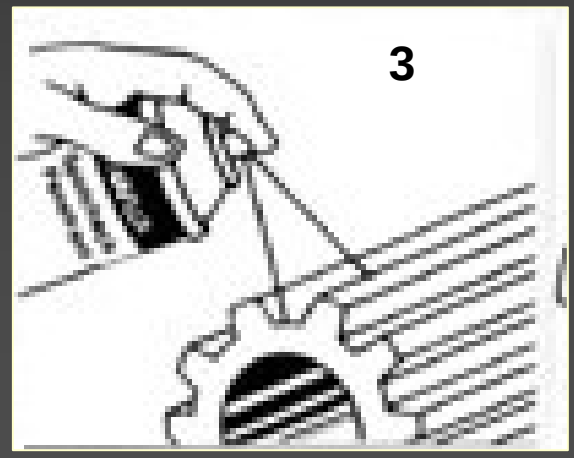
- Penetrant inspection
- Magnetic particle inspection
- Eddy current inspection
- Radiography inspection
- Ultrasonic inspection
- Borescope inspection

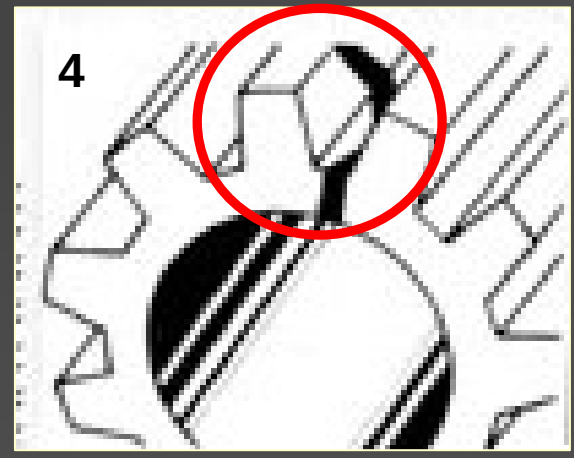
Penetrant inspection

- Detects only surface cracks
- Easiest method

1 - Cleaning
2 - Drying
3 - Dye application
4 - Inspection







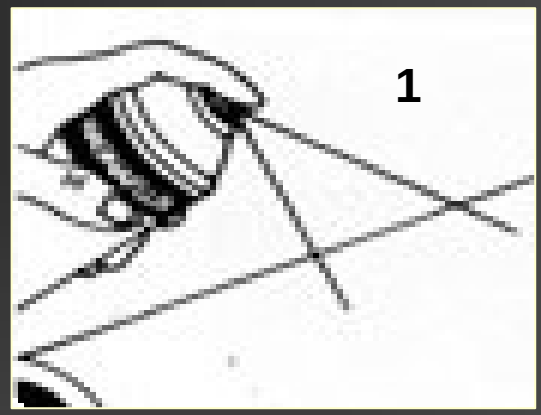
Penetrant inspection

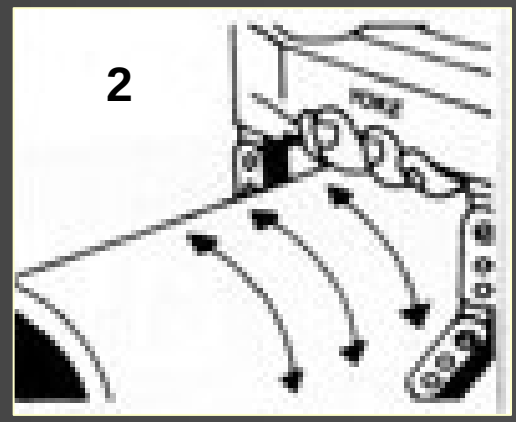
crack

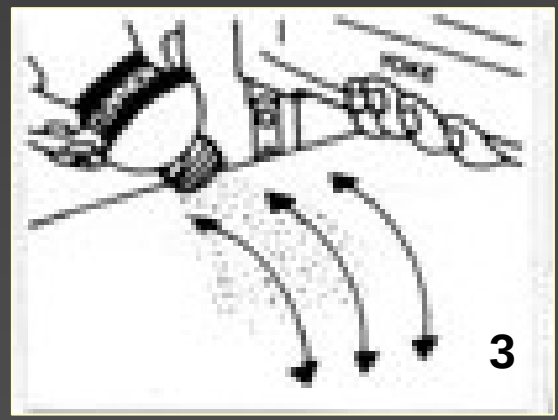
Magnetic particle inspection

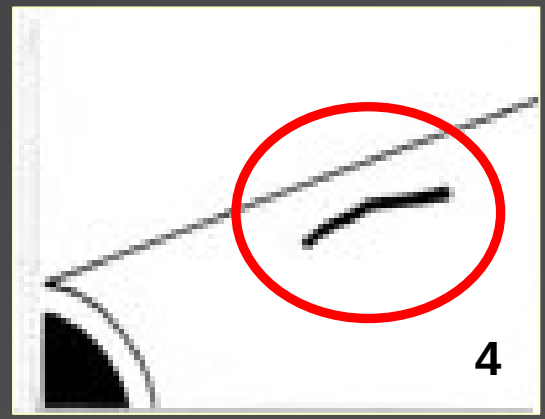
Detects surface or near-surface cracks only in ferrous parts.

1 - Cleaning
2 - Magnetization
3 - Powder application
4 - Inspection

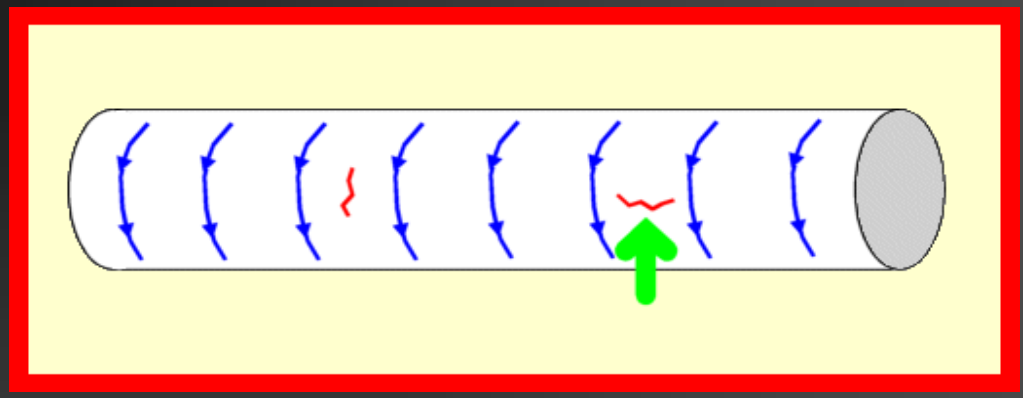




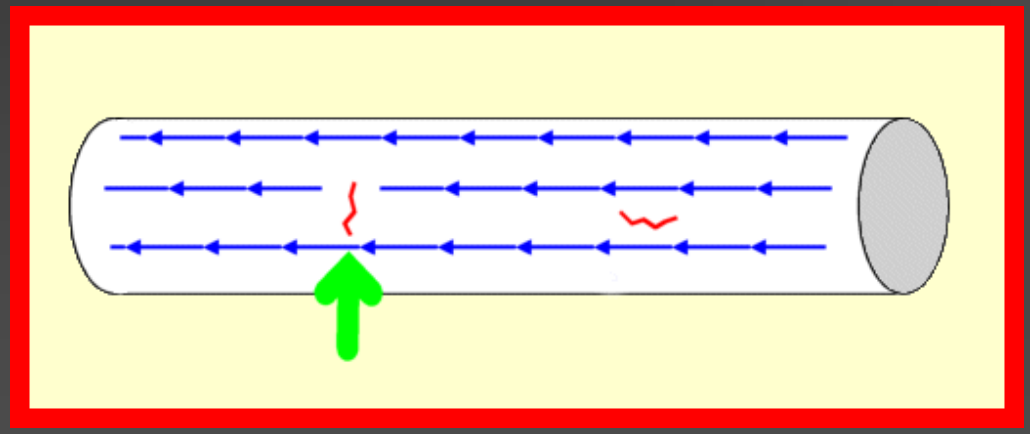




Magnetic particle inspection

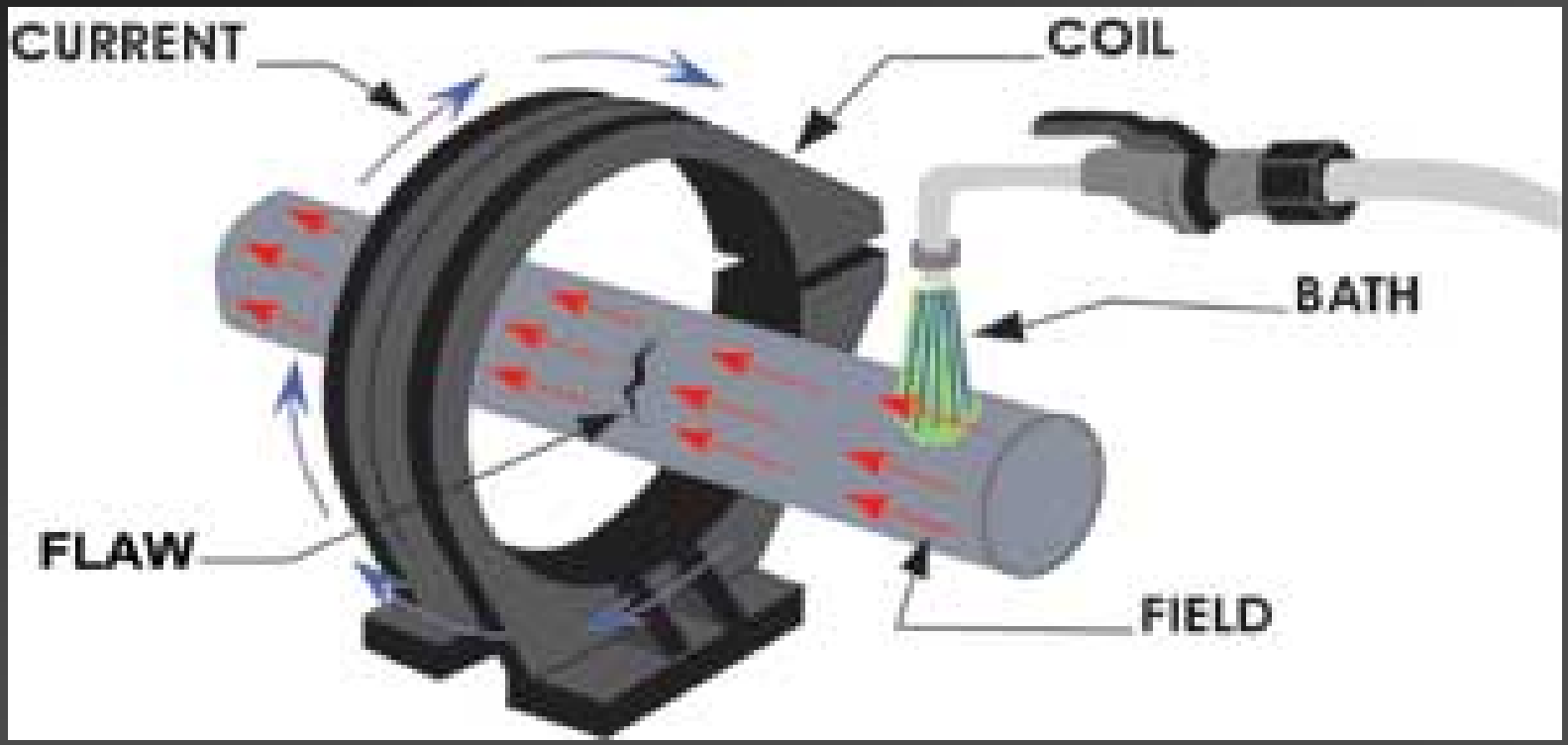


Lateral magnetization

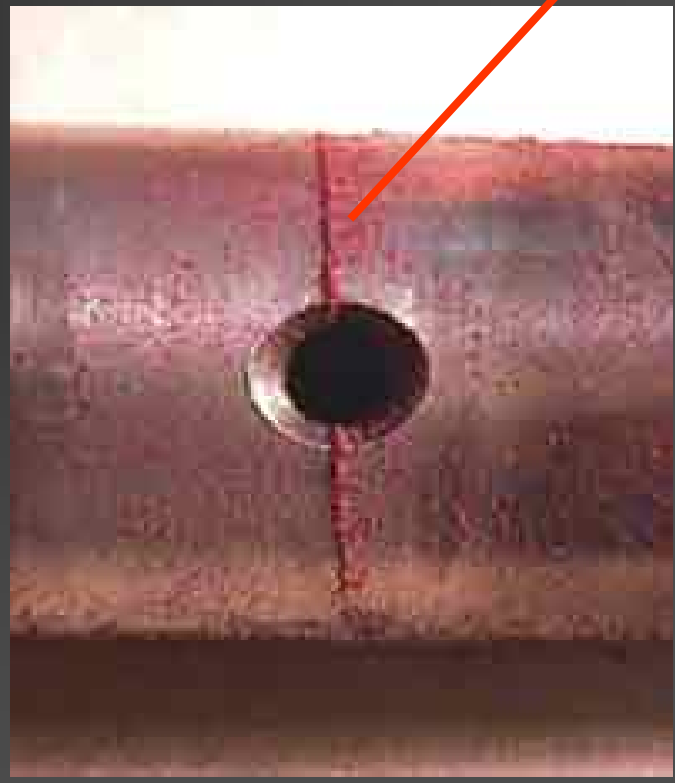


Longitudinal magnetization

Magnetic particle inspection

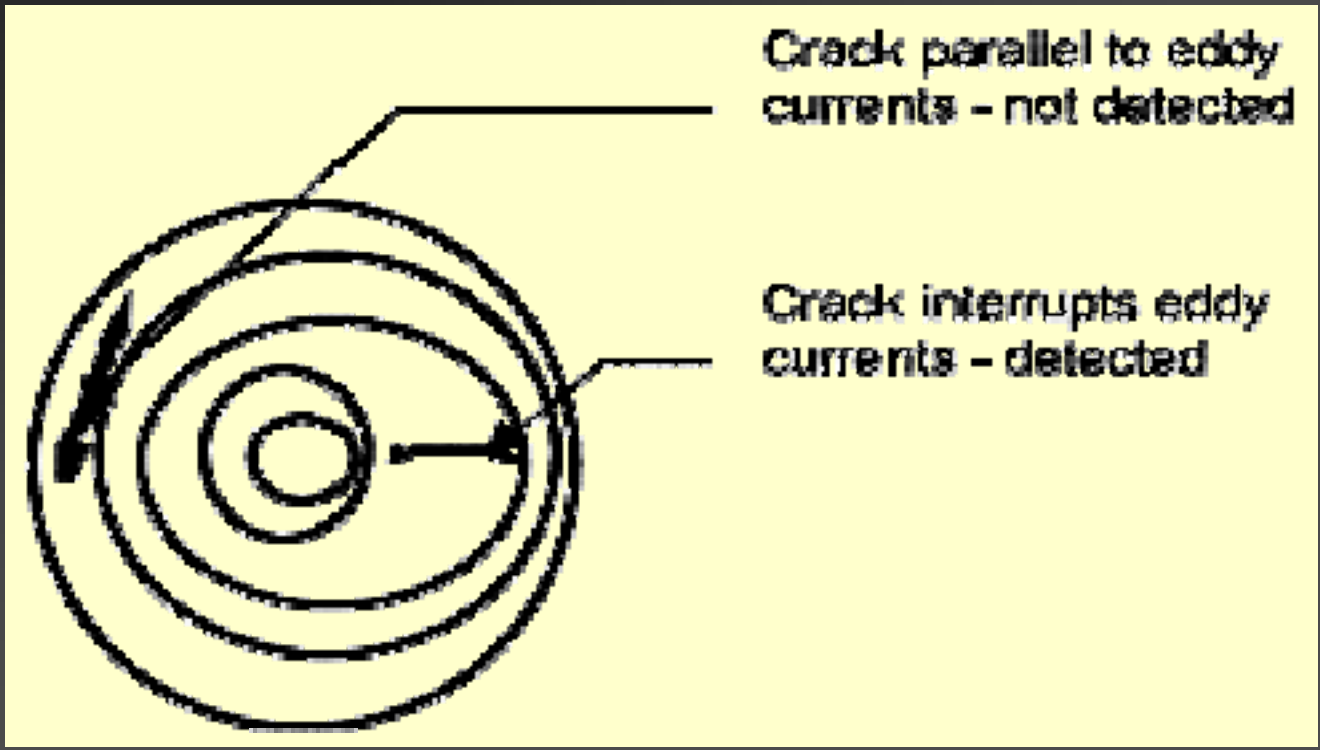


Magnetic particle inspection

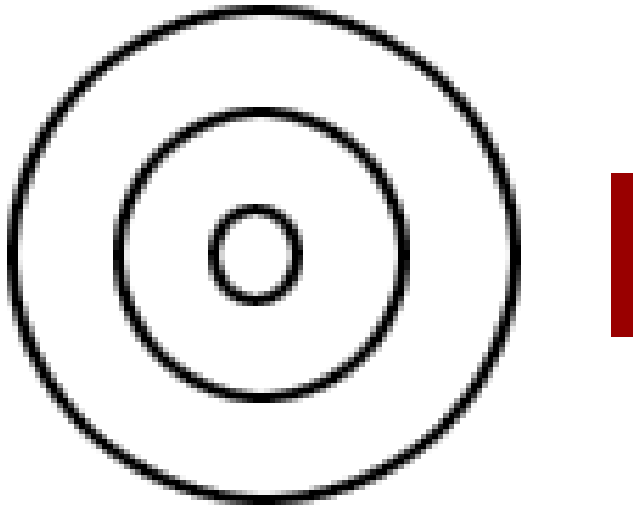


Eddy current testing

Detect surface or near-surface cracks in conductive parts.

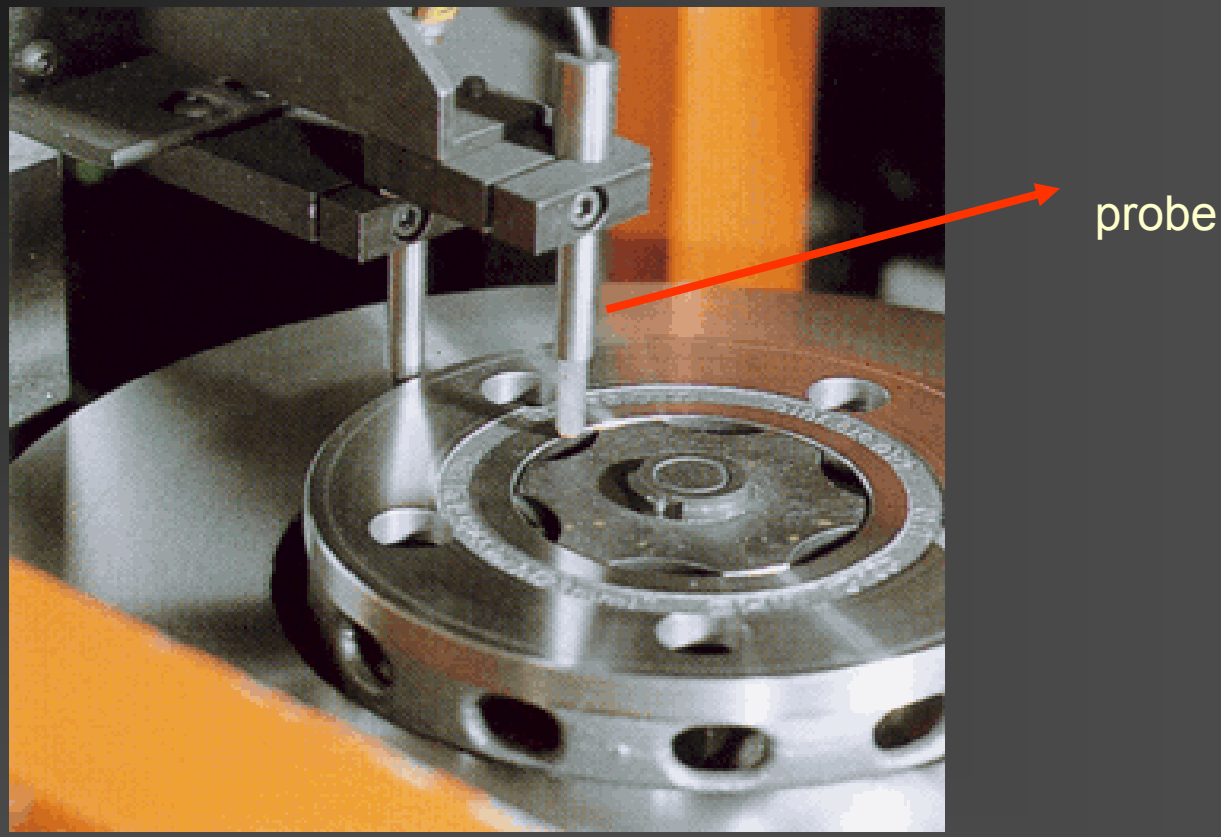


Eddy current testing



crack parallel to eddy currents - not detected

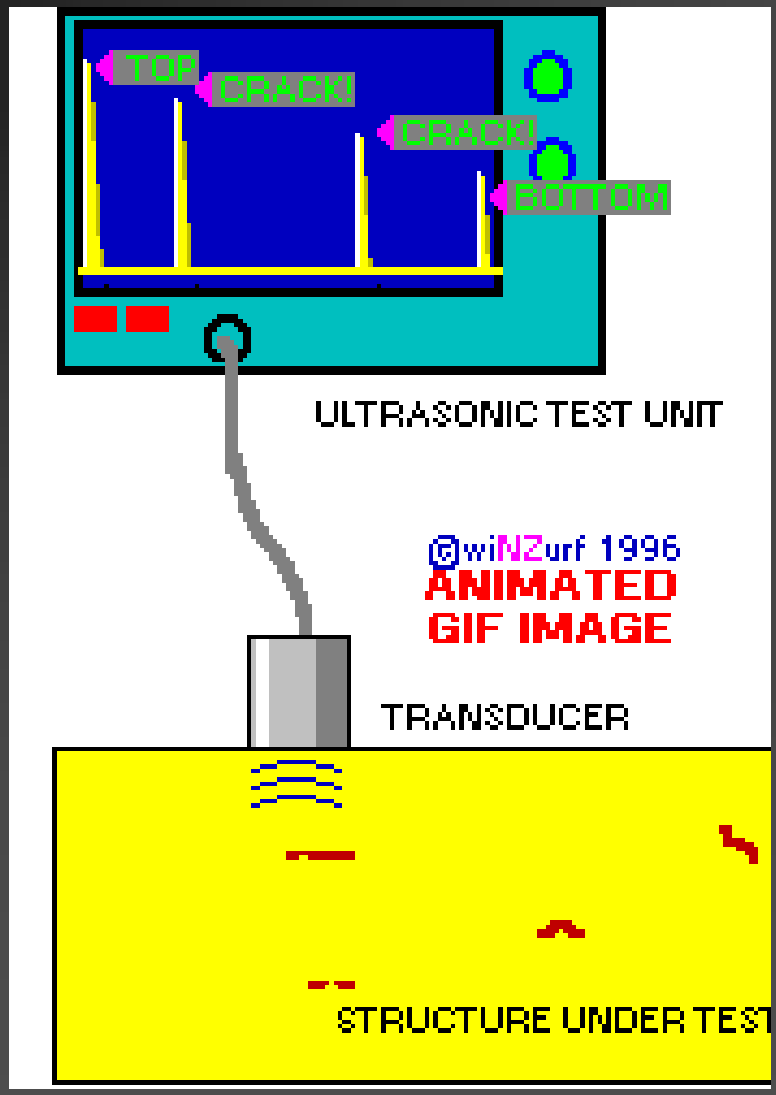
Eddy current inspection probes



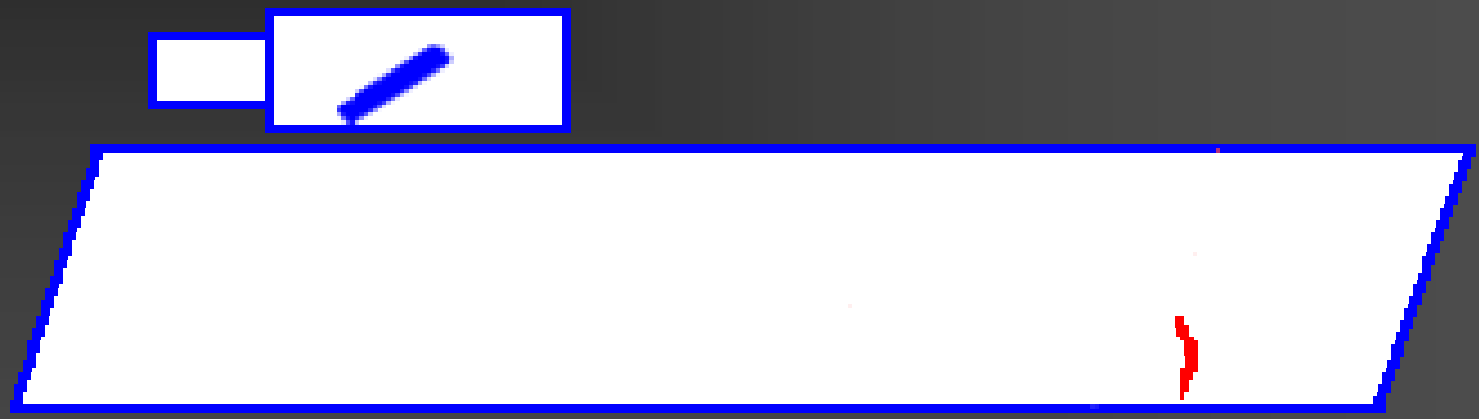
Ultrasonic inspection

It can detect cracks inside the metallic & nonmetallic part.

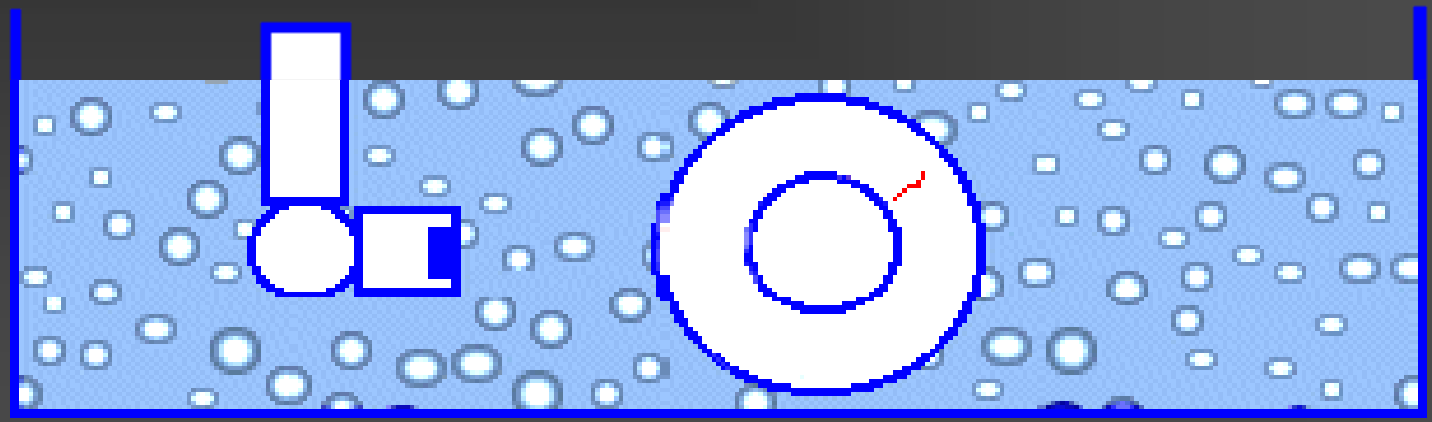
Ultrasonic inspection



Ultrasonic inspection techniques (angular application)



Immersed ultrasonic inspection



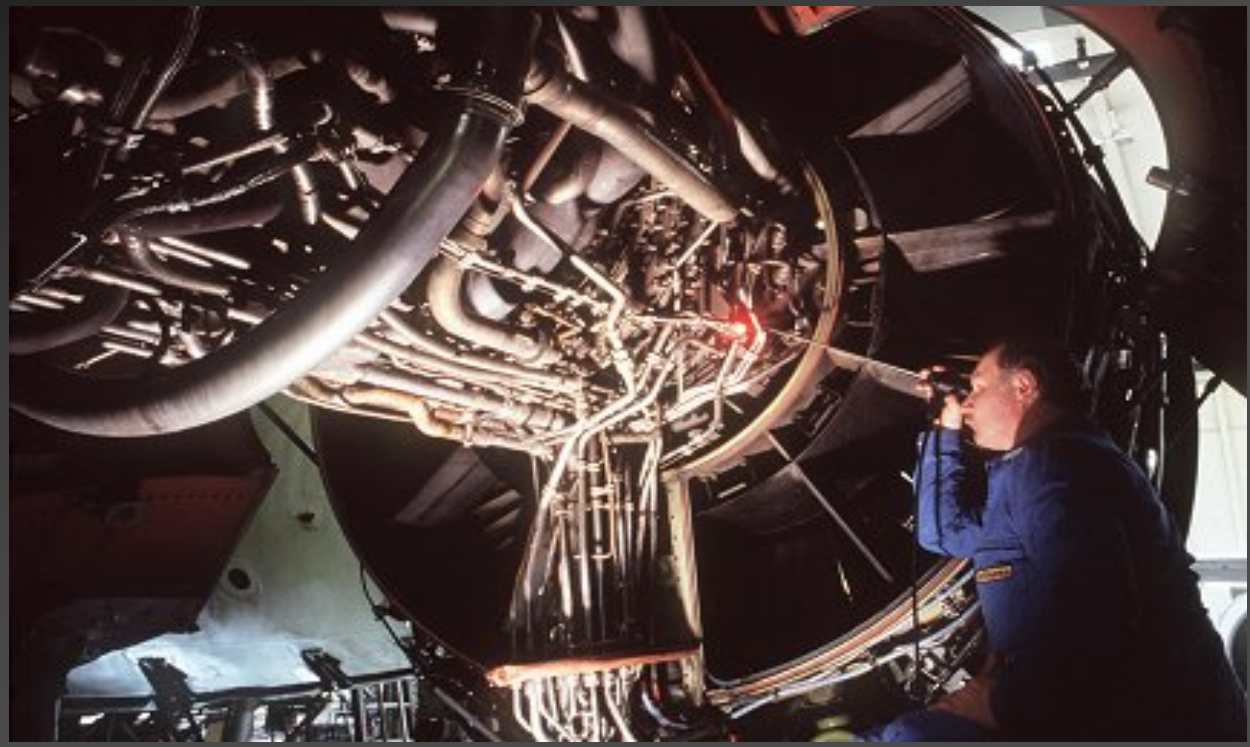
Radiography Inspection

It can be used to detect crack inside the ferrous and non-ferrous materials

Borescope inspection

It is used to inspect the areas which are hardly accessible such as engine compressor & turbine

Borescope inspection



Borescope kits

Quick reference for choosing appropriate NDI method

Discontinuity Type	Material	NDI method
Surface cracks	Nonferrous	PT/ET/RT
	Ferrous	MT/PT/RT
Sub-surface cracks	Nonferrous	RT/ET
	Nonferrous/ferrous	RT/UT
Corrosion	Nonferrous	UT/RT/ET
Laminations	Metal/composites	UT
RT=Radiographic testing	UT=Ultrasonic testing	ET=Eddy current testing
MT=Magnetic part testing	PT=Penetrant testing	

AIRCRAFT MAINTENANCE MANAGEMENT & PLANNING

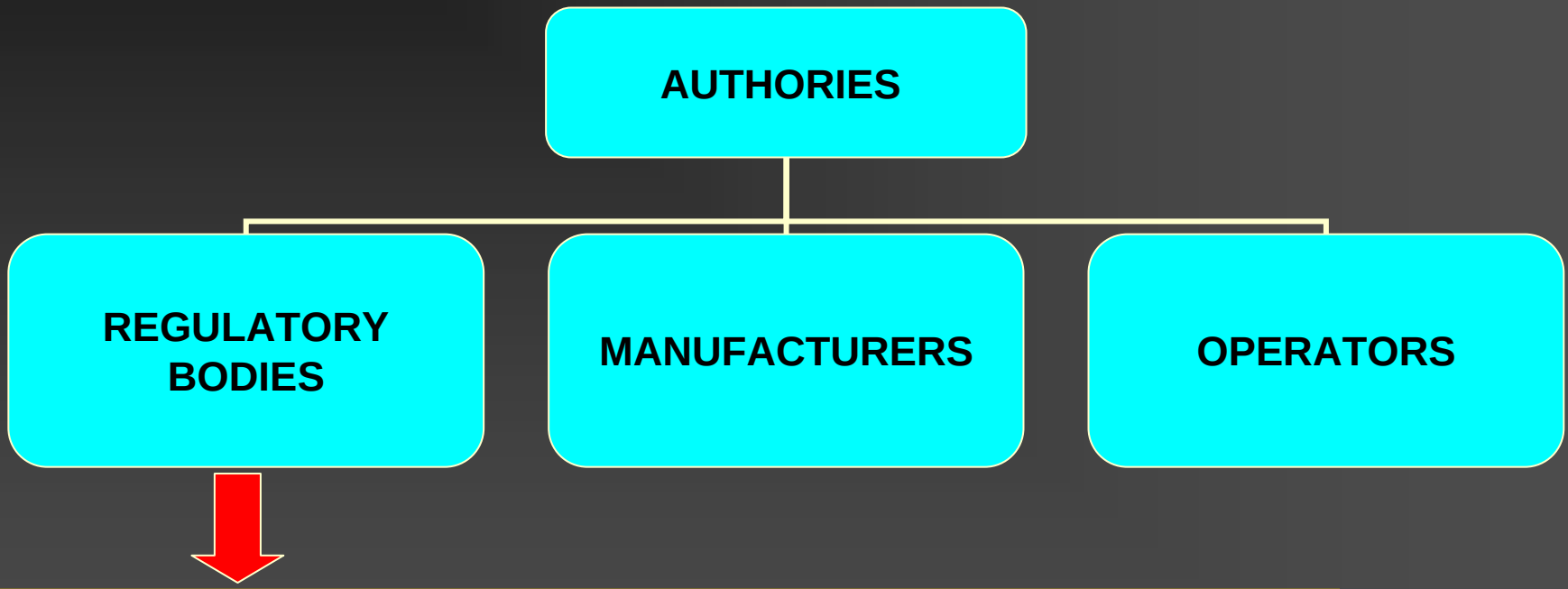
Maintenance

Maintenance is any one or combination of activities such as;

- Inspection
- Modification
- Repair
- Replacement
- Overhaul

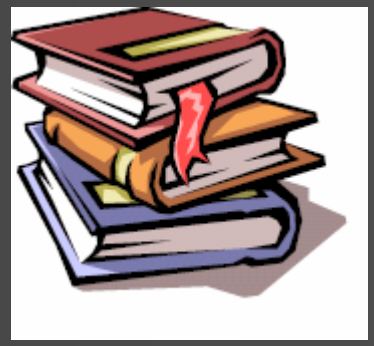
to restore an aircraft or aircraft component or to keep it in working condition.

Authorities involved in maintenance program development



- FAA (Federal Aviation administration)
- EASA (European Aviation Safety Admin.)
- ICAO (International Civil Aviation Organization)

Maintenance Regulations & Documents



- Maintenance Manuals
- Service Bulletins
- Federal Aviation Regulations (FAR)
- Joint Aviation Requirements (JAR)
- Airworthiness Directives
- Advisory Circulars
- Minimum Equipment List (MEL)
- Technical orders

Maintenance Processes

- ***Preventive maintenance***

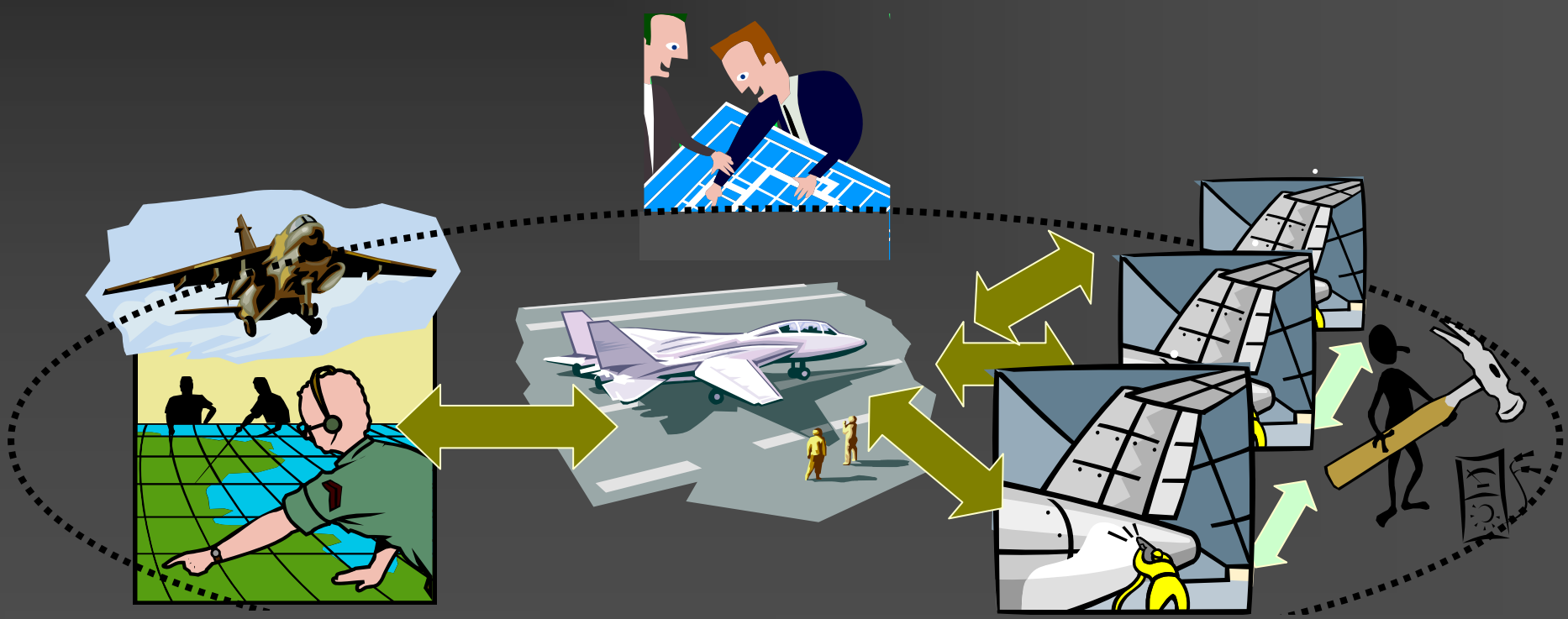
  Predictive maintenance is performed in order to prevent failure of an item or to discover a hidden failure.

- ***Corrective maintenance***

  Corrective maintenance is performed after the failure to correct the fault.

Maintenance Processes in aviation

- Hard time
- On condition
- Condition Monitoring



Hard-time Maintenance

- It is the oldest, primary preventive maintenance process.
- It requires that an appliance or part be periodically **overhauled at certain intervals** in accordance with the carrier's maintenance program, or it should be **removed** from the service.
- As soon as the part age reaches predetermined time (flight hour, cycle, or calendar time), it is overhauled or replaced with a new component.

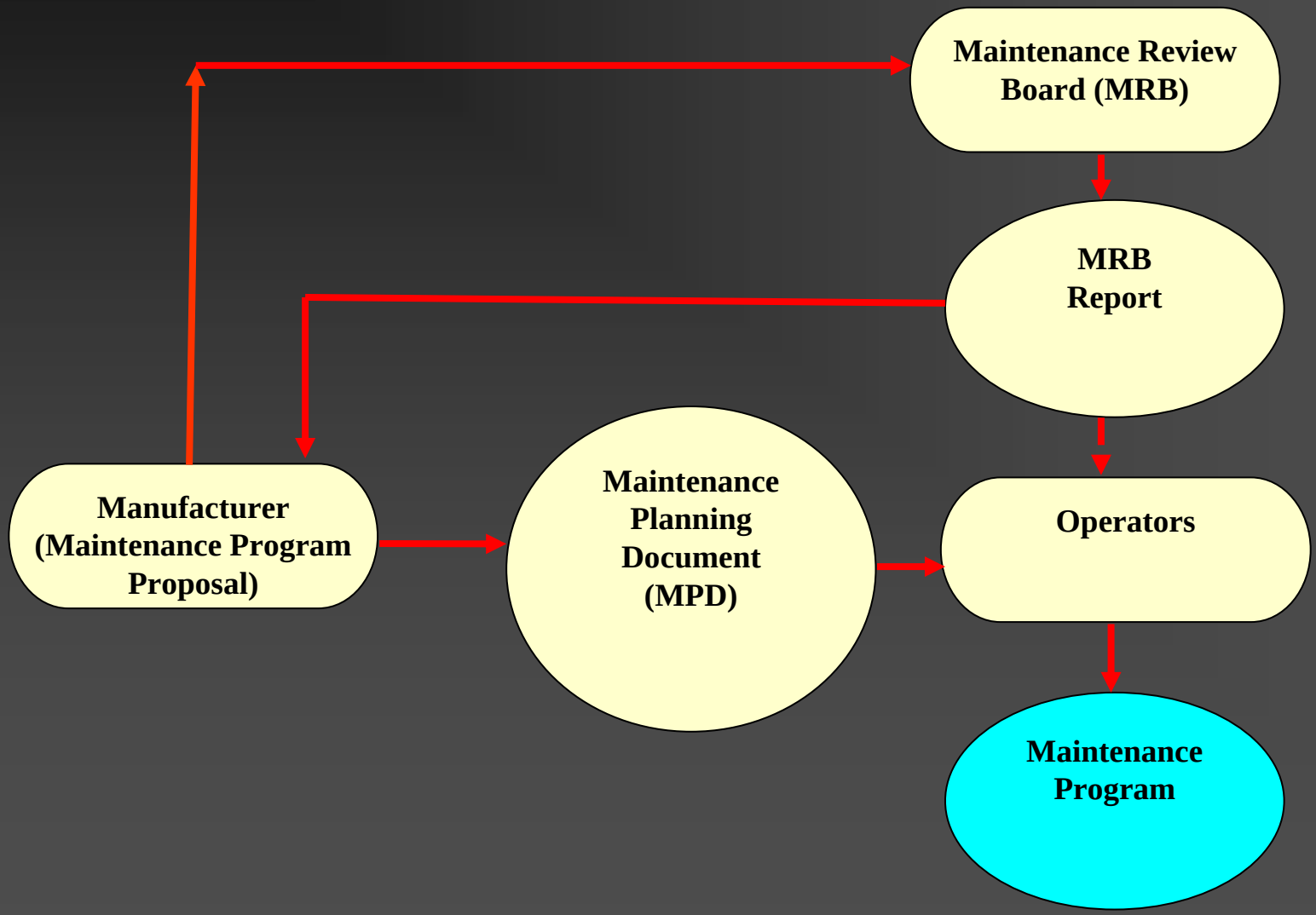
On-condition Maintenance

- This is a primary preventive maintenance process.
- It requires that an appliance or part be periodically **inspected or checked** against some appropriate physical standards to determine weather it can continue in service.
- The purpose is to use the part as long as possible before it fails during normal operation (in service operation)

Condition Monitoring

- This is a maintenance process for items that have neither “hard time” or “on-condition” maintenance as their primary maintenance process.
- Condition monitoring is the maintenance process for locating and resolving problem areas through analytical study of malfunctions or failures, not affecting safety of aircraft.

Maintenance Program Development



Aircraft operator maintenance program

An air carrier's maintenance program should contain at least the following information:

1) What (**Item** to be maintained)
2) When (**time limit**)
3) How (**task**)

1) Items to be maintained (What ?)

The item (part, component, or system) to be maintained should be indicated clearly and accurately. This is done usually by ATA (air Transport Association) Chapter numbers, part serial numbers, etc.

2) Time Limit (When ?)

- The time limit is the maintenance interval when you perform the maintenance task.
- There are three (3) units of measure used to establish these limits. An item may have no limits, one limit, or any combination of these limits.

Time Limit

- CALENDER TIME
- FLIGHT HOURS
- CYCLES (no. of landings)

3) Maintenance Tasks (How ?)

These include the maintenance services to be done. The maintenance program consists of three types of tasks:

- Scheduled maintenance tasks
- Unscheduled maintenance tasks
- Specific maintenance requirements for major components of aircraft (engine, propeller, etc.)

Types of Scheduled Maintenance Tasks (services)

- Preflight / post-flight
- Transit Service
- Overnight Heavy Service
- Heavy Maintenance Service
- Overhaul Service

Maintenance tasks and letter checks

- In maintenance program, the maintenance tasks which are carried out at the same time are grouped into maintenance packages.
- These maintenance packages are indicated by "A", "B", "C" and "D" checks. For this reason they are called "letter checks".

Transfer of task types in maintenance program

SERVICE TYPE	CHECK
OVERNIGHT HEAVY SERVICE	A
HEAVY MAINTENANCE SERVICE	C
OVERHAUL SERVICE	D

Military aircraft maintenance

	Maintenance levels		
	Ordinary (O)	**Intermediate (I)**	**Depot (D)**
Maintenance types	Pre-flight inspections, scheduled maintenance, minor failure repair	Term maintenance, failure repair	Term maintenance, damage repair
Location	Squadron	Airbase	Factory-level facility
Duration	Minutes - hours	Hours - weeks	Weeks - months
Example tasks	Refueling, minor repairs, e.g. light bulb change	Component change/repair, e.g. hydraulic pump change	Elaborate component or structure changes/repairs, e.g. bird crash repair

How to package the maintenance tasks?

There are two questions that need to be answered about the **TIME LIMIT** correctly:

1) What is the best time measurement unit (Calendar day, flight hour or cycle)?
2) What is the optimum time limit for part replacements or inspections?

1) What is the best time measurement unit for me (Calendar day, flight hour or cycle)?

Aircraft	:	Boeing 747-400
Usage by design	:	High daily flight hour utilization
“C” check interval:		15 months or 3500 flight hours

Operator A:

- Average usage : 7000 fh/year
- “C” checks: 3500 flight hour

Operator B :

- Average usage: 7000 fh/year
- “C” checks: 15 months

Result: Operator A will perform more “C” checks than Operator B which results in increase in maintenance cost with no increased level of safety and reliability.

2) What is the optimum time limit for part scheduled replacements or inspections?

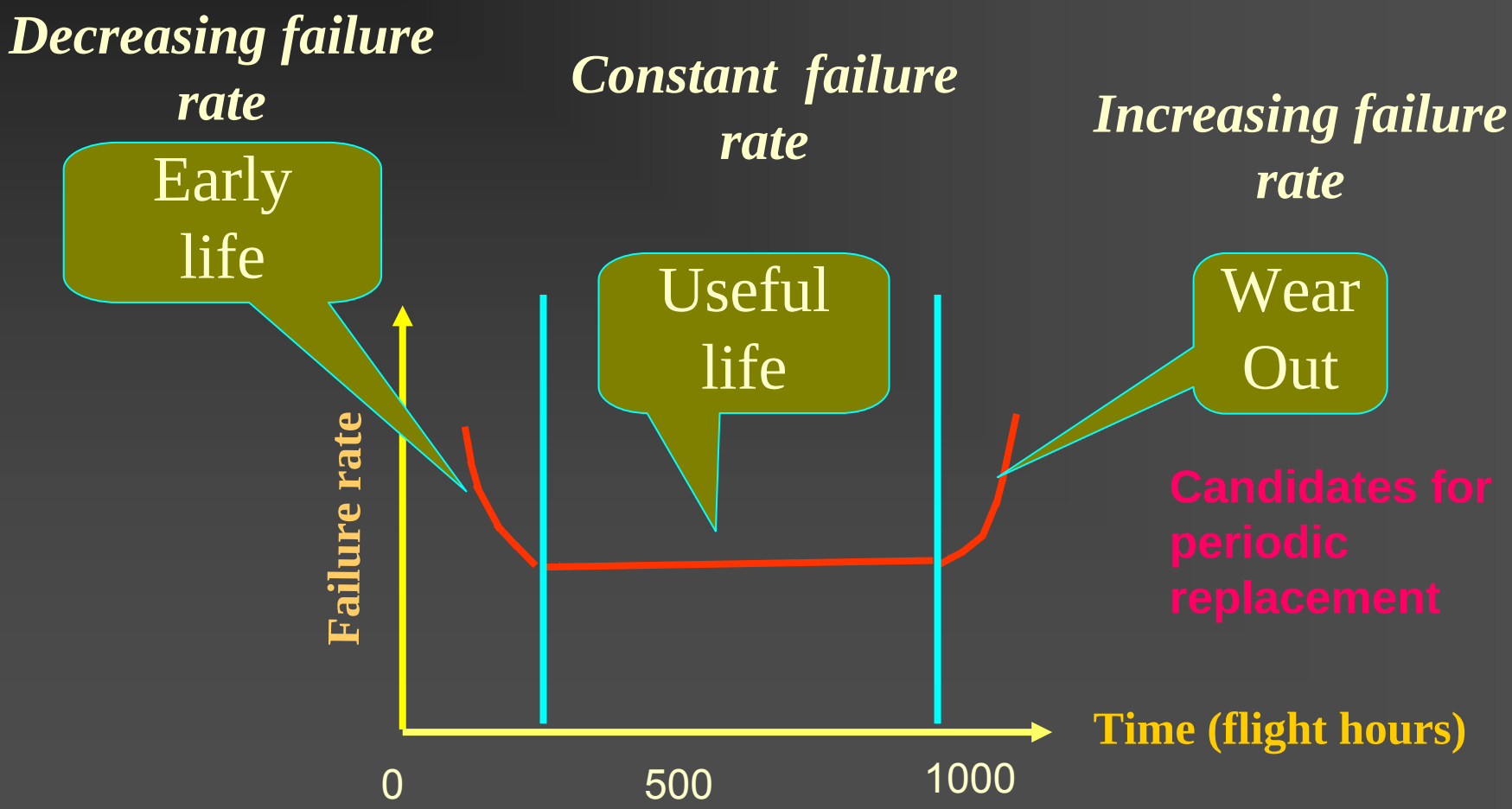
- Scheduled tasks are to be performed at regular intervals.
- Maintenance Planning Document (MPD) prepared by the manufacturer is the main document that provides the user with time intervals for various tasks.
- However, these are recommended intervals by the manufacturer. Each operator should customize these recommended time intervals based upon its own operating and environmental conditions, maintenance capabilities.
- To determine the optimal interval is a very difficult task that has to be based on information about the failure rate function.

Operating life and failures of a component

Operating life of a component may include three periods from the failures point of view:

- Early life period
- Useful life period
- Wear-out life period

Failure Characteristics of aircraft components



Early life period

- ***Early failures*** occur early in the operating life of a component and are characterized by a decreasing failure rate with increasing age.
- Main causes of early failures are:
  - Poor manufacturing techniques
  - Poor quality control
  - Improper storage of the component
  - Improper installation
  - Contamination

Useful life period

- ***Useful life period*** is characterized by constant (or random) failure rate. During useful life components fail by change unexpectedly.
- Main causes of change failures are:
  - Misapplication
  - Abuse
  - Storms, lightning, etc.
  - Foreign object damage (FOD)

Wear-out period

- ***Wear-out failures*** occur late in operating life and characterized by an increasing failure rate with increasing age.
- Main causes of wear-out failures are:
  - Aging
  - Wear
  - Fatigue
  - Corrosion and erosion
  - Poor service, maintenance, and repair.

Case study
ESTIMATION OPTIMUM TIME OF REPLACEMENT FOR AN AIRCRAFT COMPONENT

- Manufacturer's maintenance document recommends replacement of a spring in aircraft APU fuel pump at an interval of 60 flight hours.
- Although you are applying the manufacturer recommendation, fuel pump often fails unexpectedly and produce many unscheduled maintenance tasks.
- You are assigned to analyze and recommend solution to this problem.

STEP#1: Collection and Arrangement of Failure Data

Failure No	Time to failure (aircraft flight hour)
1	10
2	15
3	25
4	38
5	53
6	65
7	75
8	88

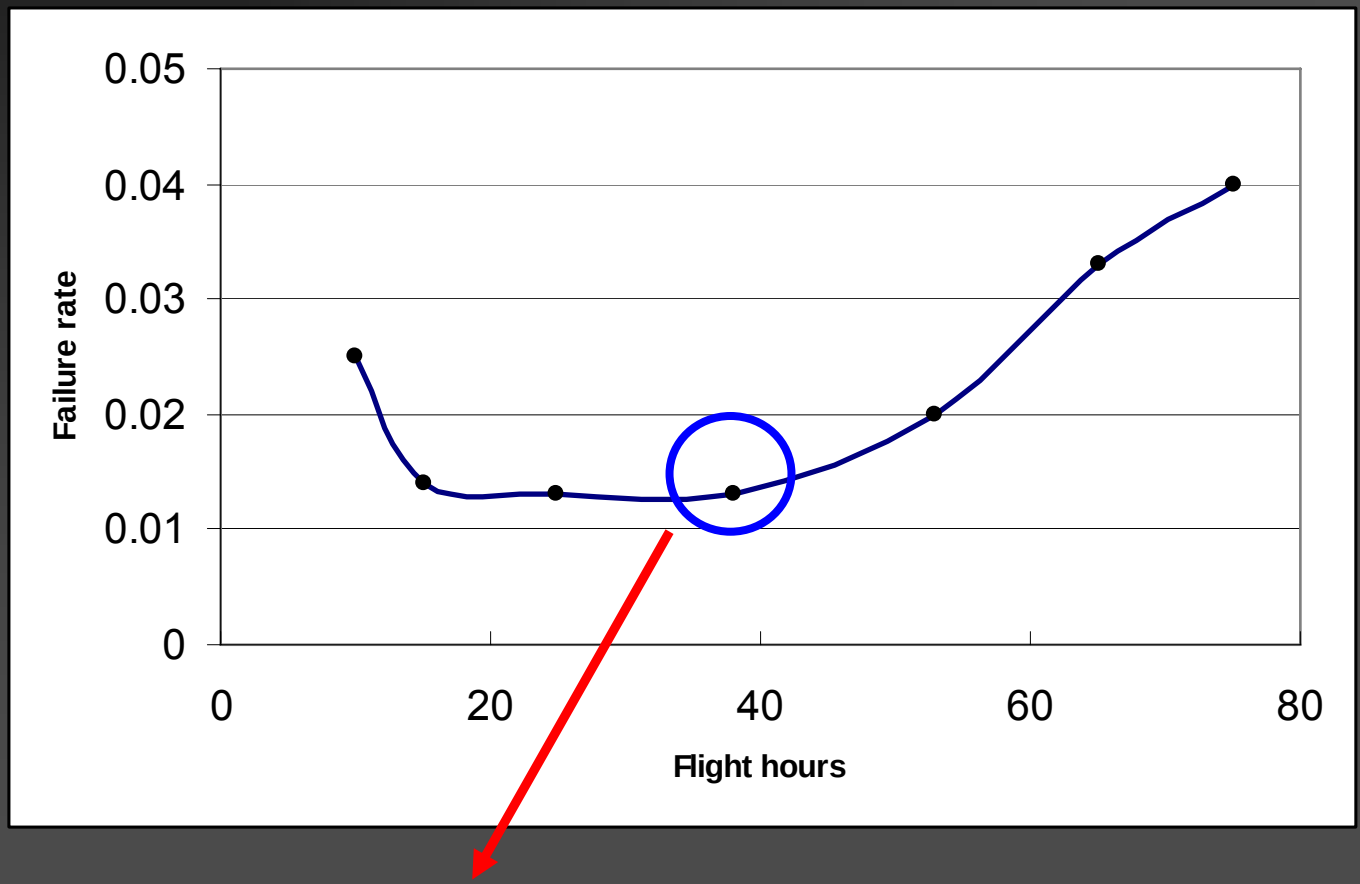
STEP#2: Calculation of failure rate

Failure Number (i)	Time to failure (flight hour)	Time between failures Δt	Failure rate $FR = \frac{1}{(\Delta t)(n+1-i)}$
1	10	15-10=5	1 / [(5)(8+1-1)]=0.025
2	15	25-15=10	0.014
3	25	13	0.013
4	38	15	0.013
5	53	12	0.020
6	65	10	0.033
7	75	13	0.040
8	88		

n= 8 (total number of failures)

STEP#3 : Analysis

Plot column # 4 vs. Column # 2



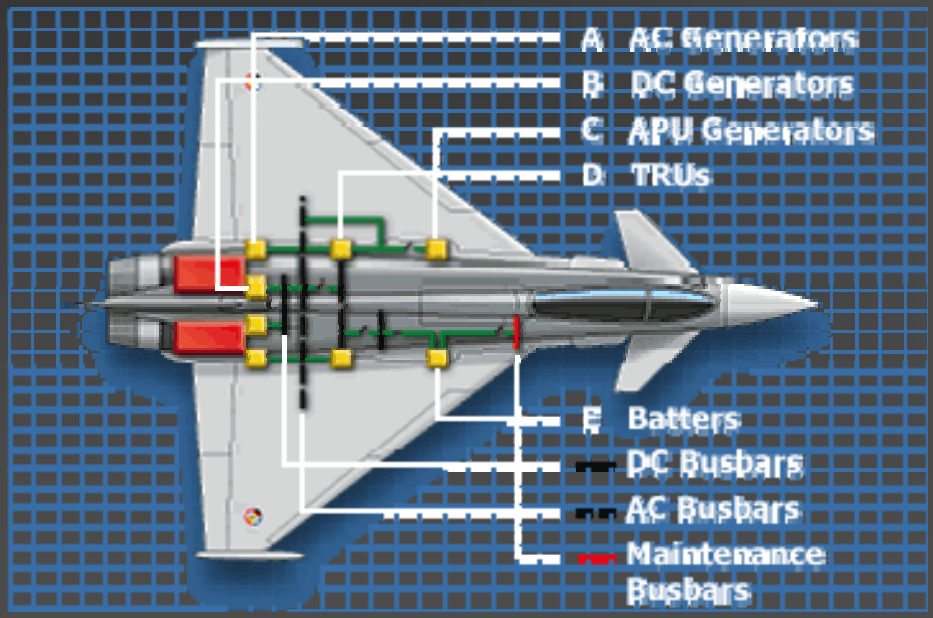
This is the optimum replacement time

CONTINUOUS AIRWORTHINESS MAINTENANCE PROGRAM (CAMP)

- A continuous airworthiness maintenance program (CAMP) is the set of processes certificate holders (operators) must use to keep their aircraft in an airworthy condition.
- The FAA requires operators to establish and maintain two separate, but equal, functions within their CAMP :

  - required maintenance actions
  - required maintenance inspection

AIRCRAFT ELECTRICAL SYSTEM



Electrical System

- Electrical Power sources
- Electrical Components
  - Control devices
  - Conversion devices
  - Protection devices.
- Power distribution systems and loads

Electric Power Sources

Aircraft equipments operate at two electrical power levels

- 115 VAC @ 400 Hz
- 28 VDC

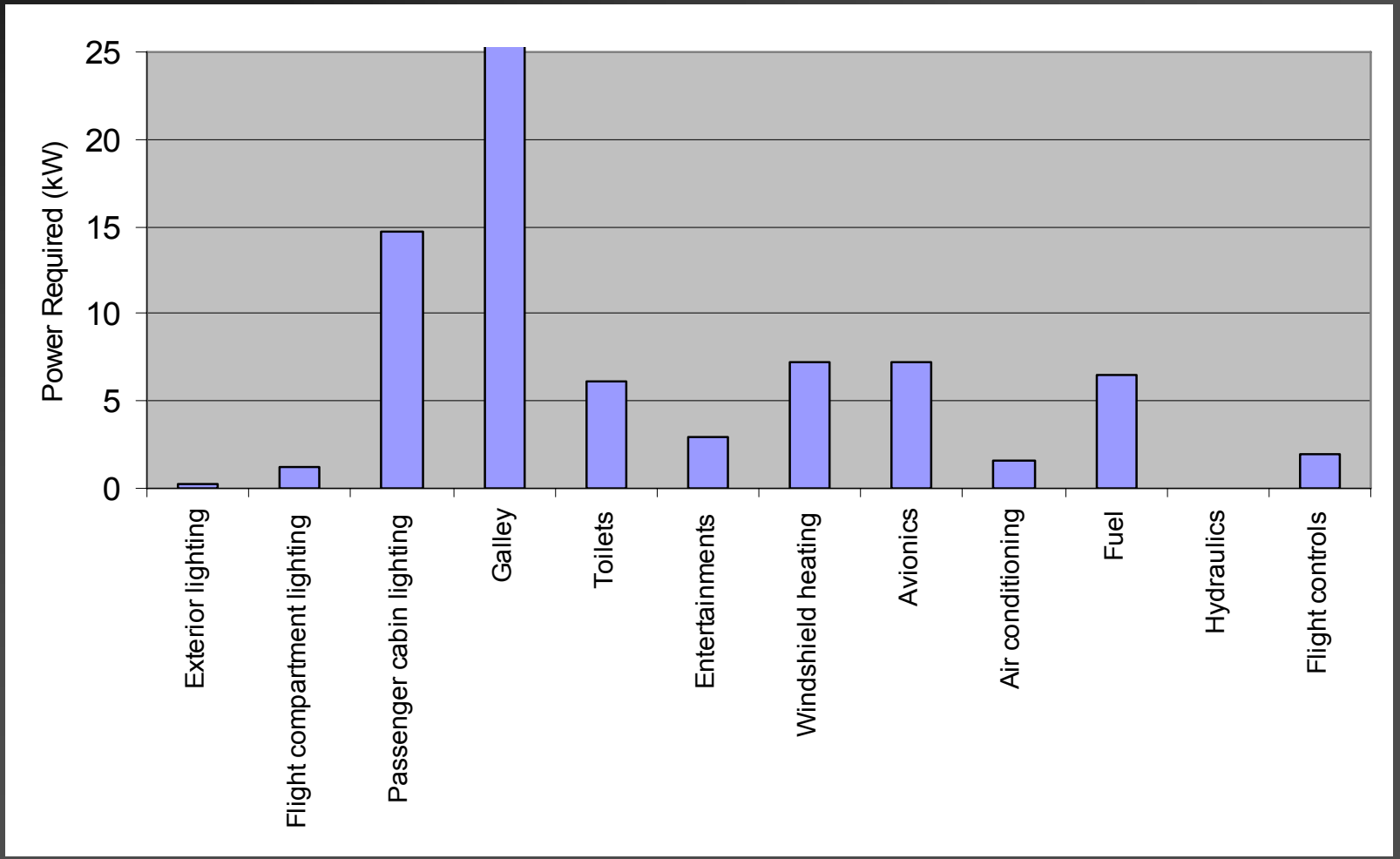
There are two power sources on the aircraft to generate these electric powers:

- Batteries
- Generators

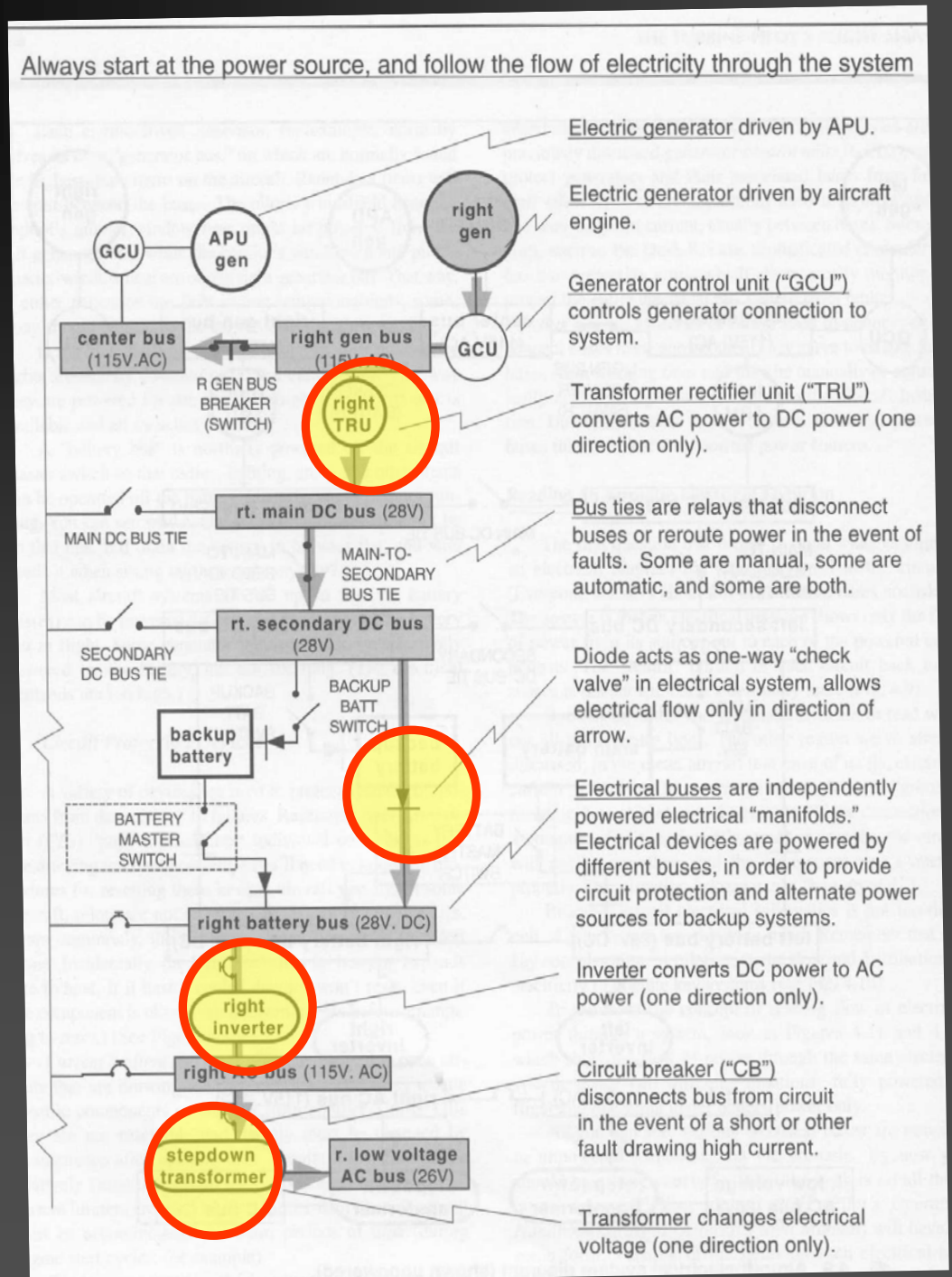
Ni-Cd Battery

Generator

Electrical power requirements during a typical flight



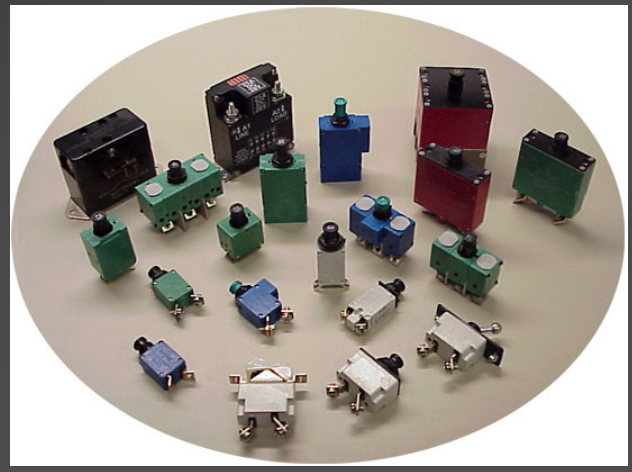
ELECTRICAL SYSTEM COMPONENTS



Electrical components

RELAY

Transformer rectifier unit (TRU)



CIRCUIT BREAKERS

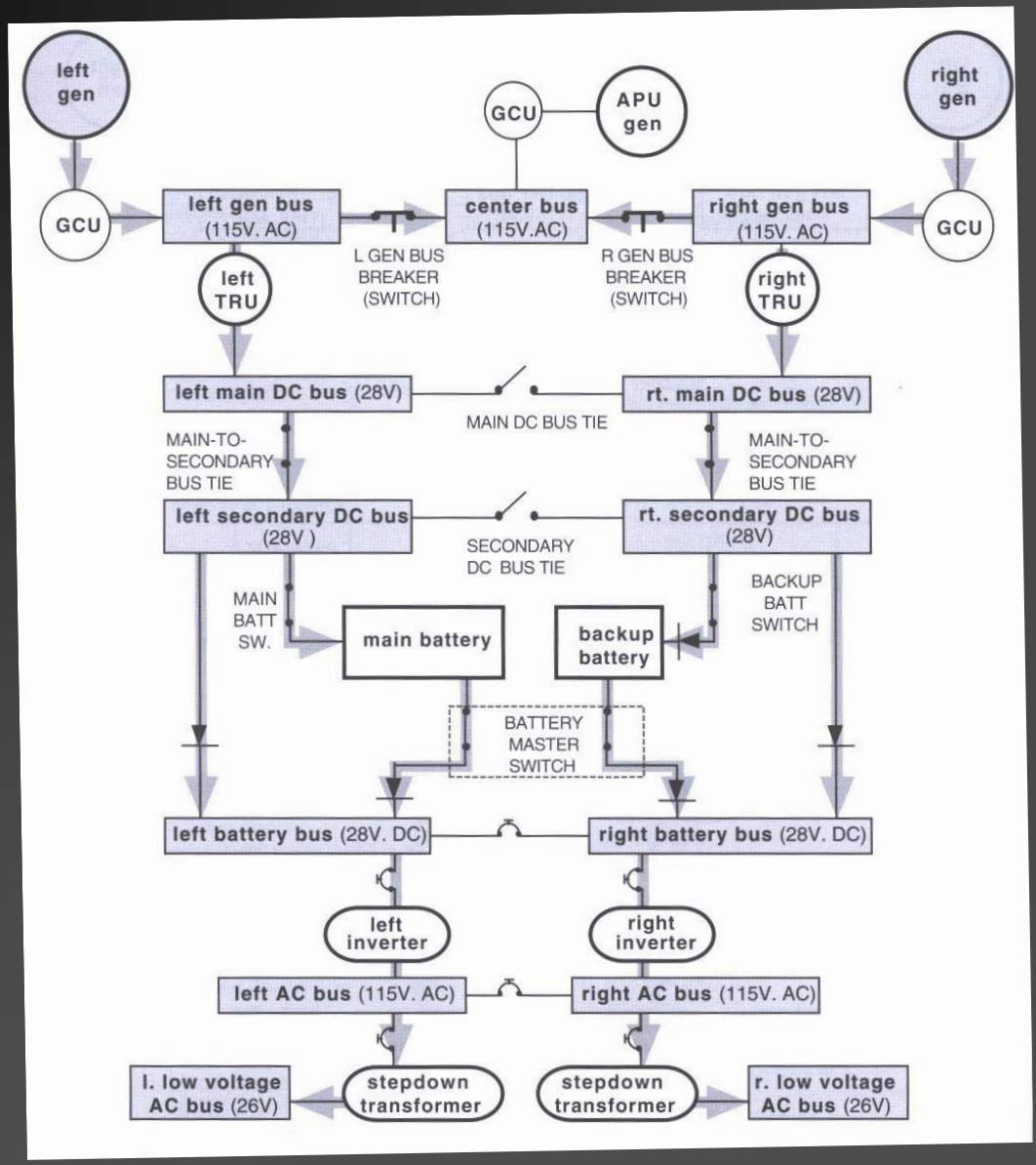
Main electrical system troubles

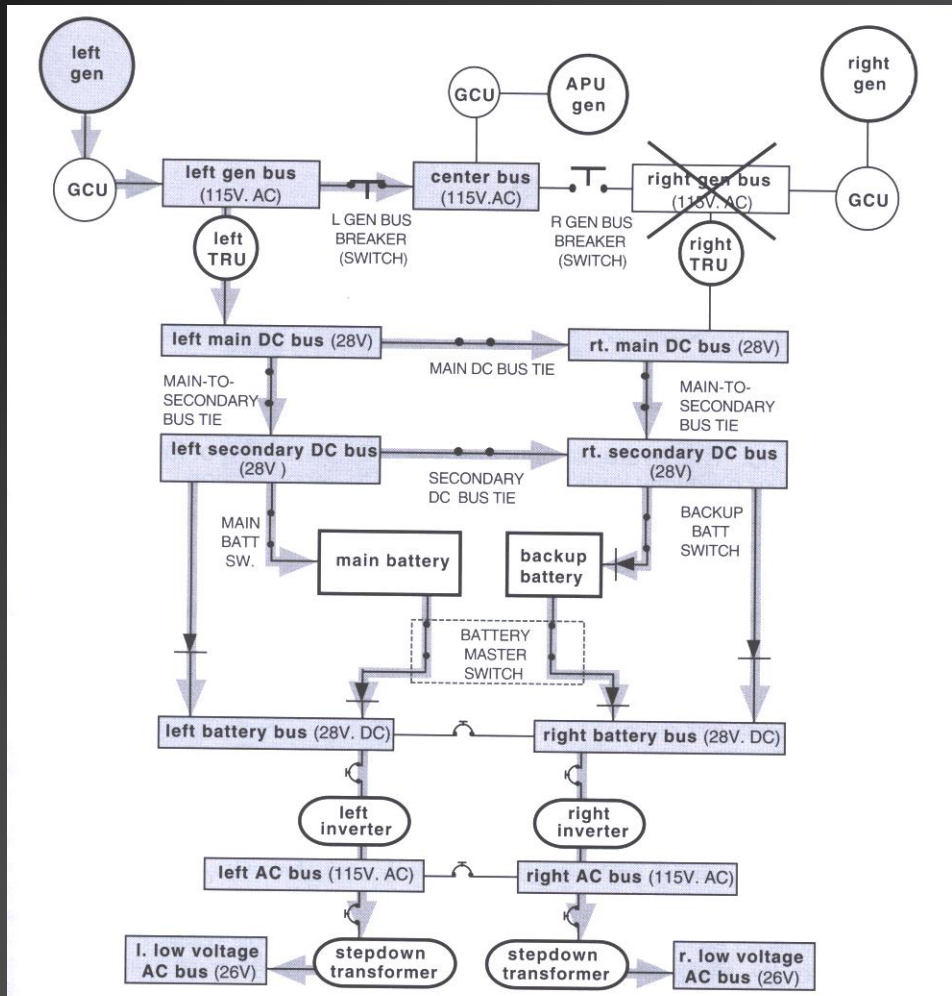
Open circuit : Circuit that is not complete or continuous. When an open occurs the affected component stop to operate, but the other components still remain in operative condition.

Short Circuit: It occurs when electricity is allowed to take a shortcut through or around a component or system. It has two effects:

- Affected components have no power and fail to operate
- The other component will be subjected to higher level of current causing them to burnout.

Aircraft electrical system diagram





Right generator bus has been isolated due to fault. Pilots would be notified by caution or warning light, plus loss of various electrical components. Right GCU has taken right generator off line. Left generator is now powering all buses except for the "right gen bus." Any components on that bus are unpowered, and plans must be made to complete the flight without them. Course of action begins with pilot call for "Generator Bus Failure Checklist."

CAMP

- SCHEDULED MAINTENANCE
- AIRCRAFT INSPECTION
- UNSCHEDULED MAINTENANCE
- RELABILITY CONTROL